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# ORGANIC FOOD AND HUMAN HEALTH – A REVIEW

*Summary*

*The presented study gives an overview of recently published research investigating the health value of organic foods. Some in vitro studies indicated higher antimutagenic and antioxidant activity, as well as more effective inhibition of cancer cell proliferation by organic compared to conventional foods. Most of the well-designed animal model experiments carried out so far have demonstrated significant differences in weight, growth, fertility, hormonal and immune status of organically versus conventionally fed laboratory animals, but interpretation of the identified differences needs further investigation. Big scale epidemiological studies of human population found negative association between organic food consumption and risk of skin allergies. Another research group has recently reported association of organic diet with lower incidence of non-Hodgkin lymphoma, but no relation between organic food consumption and overall incidence of cancers, soft tissue sarcoma and breast cancer. Findings of very few human intervention studies carried out so far are very ambiguous. On the basis on the currently available data no indisputable conclusions can be drawn. As research results on this topic can undoubtedly count on high societal interest, more comprehensive, well designed animal and human interventions are needed.*
***Key words**: organic food, organic farming, human health, nutrition, cancer, antioxidants, bioactive compounds*

# WPŁYW ŻYWNOŚCI EKOLOGICZNEJ NA ZDROWIE CZŁOWIEKA – PUBLIKACJA PRZEGLĄDOWA

*Streszczenie*

*Niniejszy artykuł stanowi przegląd literatury naukowej podejmującej temat wpływu żywności ekologicznej na zdrowie człowieka. Wyniki opublikowanych w ostatnich latach badań in vitro wskazują na silniejsze działanie antymutagenne oraz antyoksydacyjne, a także bardziej skuteczne hamowanie proliferacji komórek nowotworowych przez ekstrakty z ekologicznych w porównaniu do konwencjonalnych płodów rolnych. W większości spośród przeprowadzonych dotychczas dobrze zaplanowanych eksperymentów z wykorzystaniem modeli zwierzęcych wykazano istotne różnice w parametrach związanych ze wzrostem i rozwojem, masą ciała, płodnością, a także statusem hormonalnym oraz immunologicznym zwierząt żywionych karmą ekologiczną i konwencjonalną, jednak interpretacja zidentyfikowanych różnic wymaga dalszych badań. Wielkoskalowe badania epidemiologiczne z działem ludzi wykazały ujemną korelację między spożywaniem ekologicznego mleka i ryzykiem wystąpienia alergii skórnych. Inny zespół naukowców stwierdził ujemną zależność między dietą bazującą na produktach ekologicznych i częstotliwością występowania chłoniaka nieziarniczego. Jednocześnie nie stwierdzono jednak związku między konsumpcją żywności ekologicznej a występowaniem nowotworów ogółem, mięsaka tkanek miękkich oraz raka piersi. Wyniki niewielkiej liczby opublikowanych dotychczas badań interwencyjnych z udziałem ludzi nie są jednoznaczne. Na podstawie obecnie dostępnych danych nie można wyciągnąć wniosków na temat wpływu żywności ekologicznej na zdrowie. Jako że temat ten stanowi obecnie przedmiot zainteresowania wielu konsumentów, kompleksowe, dobrze zaplanowane badania modelowe oraz badania interwencyjne z udziałem ludzi są niezbędne.*
***Słowa kluczowe**: żywność ekologiczna, rolnictwo ekologiczne, zdrowie człowieka, żywienie, nowotwory, antyoksydanty, związki bioaktywne*

## 1. Introduction

Demand for organic foods is strongly driven by consumers' perception that they are more nutritious and can help them to maintain good health [1]. Over the last 25 years, a significant number of research studies have compared the concentrations of nutritionally relevant minerals, toxic metals (e.g. Cd and Pb), pesticide residues, macronutrients (e.g. protein, fat and carbohydrates), bioactive compounds (e.g. phenolics and vitamins) and fatty acids in foods coming from organic and conventional production systems [2-4]. Several systematic literature reviews have recently analysed the available published information, with the aim of identifying the effects of organic and conventional production protocols on the nutritional quality of foods [4-7]. Authors of the most recent and comprehensive meta-analysis summarizing results of 343 peer-reviewed comparison studies of organic *vs*. conventional foods have concluded that organic crops are, on average, characterized by significantly higher concentrations of antioxidants (*i.e.* phenolic compounds), lower concentrations of cadmium and at least four times lower incidence of pesticide residues than their conventional comparators, when compared across regions and agricultural seasons. In case of fruit, the reported incidence of detectable pesticide contamination was near 7 times lower in organic *vs*. conventional samples [3]. What is more, a number of comparative studies showed higher levels of omega-3 fatty acids in milk from organically raised animals [8]. The evidence also suggests that choosing organic over conventional meat may definitely reduce consumers' exposure to antibiotic-resistant bacteria [7]. As already mentioned, many of the bioactive compounds and beneficial fatty acids found often in higher concentrations in organic foods have previously been linked to

a reduced risk of chronic diseases, including cardiovascular disease, neurodegenerative diseases and certain cancers. Negative (*i.e.* carcinogenic) effects of cadmium and pesticide residues found more frequently in conventional products are also well proven [9-11]. On the basis of the above statements one could expect beneficial health impacts of organic compared to the conventional foods. However, the available research outcomes addressing this topic are very limited. The presented study gives an overview of recently published research investigating the health value of organic foods.

## 2. *In vitro* and animal studies

Study of Olsson et al. [12] indicated stronger *in vitro* anticancer effect (antiproliferative activity against colon and breast cancer cells) of organic strawberry extracts in comparison with extracts from conventional farming, which was probably due to a higher content of secondary metabolites with anti-carcinogenic properties in these fruits. Kazimierczak et al. [13] demonstrated higher levels of late apoptosis and necrosis of AGS human stomach cancer cells induced by organic compared to the conventional fermented beetroot juices. *In vitro* conditions enable to study precisely mechanisms of actions and to control many confounding variables. However, weakness of this type of studies is the uncertainty that the effects observed at cell level would occur in the complex living organism. Whether there is a clear correlation between *in vitro* antioxidant and anticancer effects of foods and their *in vivo* activity, it also undoubtedly depends on factors such as e.g. composition of diet, food processing conditions, gut microbiota, metabolism. However, most of the well-designed *in vivo* animal experiments carried out so far have demonstrated significant differences in weight, growth, fertility, hormonal and immune status of organically *versus* conventionally fed animals. Controlled studies on animal models have reported that diets based on organic crops have significant effects on the reproductive ability [14, 15], immune system [16-18], and development of rats, rabbits, and chickens. Chickens on an organic crop-based diet had higher immune system reactivity and improved growth rates following an antigenic challenge than chickens on a conventional diet [18]. Also, higher lymphocyte proliferation, blood immunoglobulin concentrations, and immune system reactivity was recorded in rats fed organic rather than rats fed a conventional diet [16, 17]. In contrast, a recent study by Jensen et al. [19] reported no significant differences in rat growth and a range of health biomarkers (including blood glucose, nonesterified fatty acids, triacylglycerol, cholesterol, plasma insulin, phospholipid-choline, aspartate-aminotransferase, urea-N, immunoglobulins, and plasma and liver antioxidants) between rats raised on feeds produced from conventional or organic crops, except for IgG. Średnicka-Tober et al. [20] analyzed the effect of contrasting crop protection (with or without chemosynthetic pesticides) and fertilization (manure or mineral fertilizers) regimes on feed composition as well as growth and the physiological parameters of rats. They reported that the use of manure instead of mineral fertilizers in feed production resulted in lower concentrations of protein and cadmium but higher concentrations of polyphenols in feeds, and higher body protein, body ash, white blood cell count, plasma glucose, leptin, insulin-like growth factor 1, corticosterone, and spontaneous lymphocyte proliferation, but lower plasma testosterone and mitogen stimulated proliferation of lymphocytes in rats. At the same time the authors have found no main effects of crop protection on the rat physiological parameters, although a range of significant interactions between fertilization and crop protection occurred. Even though interpretation of the identified results needs further investigation, the *in vivo* animal research undoubtedly sheds light on the topic of the health effects of organic foods.

## 3. Human subject research

A number of human subject studies on the health effects of organic compared with conventional foods have been published in recent years. Some of them focused on major public health concerned such as allergies and cancers [21, 22], other measured selected health markers such as serum lipid or vitamin levels [23]. There were also studies undertaking the topic of antioxidant status of the organism after consuming organic diet [24-27], and, finally, publications comparing the exposure of organic versus conventional food consumers to pesticides [28, 29]. As current research underlines the need of holistic looking at lifestyles rather than the diet itself, some authors analyzed different aspects of organic and conventional food consumers' lifestyles, in relation to self-assessment of their health status [30-32].

### 3.1. Organic foods and allergies

As the prevalence of allergic diseases has increased rapidly in recent decades, particularly in children, it is undoubtedly important to take steps towards prevention of allergies. Identification of risk factors, but also possible protective factors, is one of the challenges in building the prevention strategies. Alfven et al. [33] aimed therefore in their study to compare the prevalence of allergic diseases and sensitization between farm children, children in anthroposophic families and reference children, to identify factors (related to living environment and lifestyle, including diet) that may protect against allergic diseases. This cross-sectional study included 14,893 children, aged 5-13 years, from farm families, anthroposophic families (recruited from Steiner schools) and reference children in Austria, Germany, The Netherlands, Sweden and Switzerland. The authors found that growing up on a farm, as well as leading an anthroposophic life style (including biodynamic and organic food), has a protective effect against wheezing, atopic eczema and asthma, as well as sensitization measured by the blood level of allergen specific IgE. Another study on organic diet and allergies (KOALA Birth Cohort Study in the Netherlands including about 2700 newborns) associated the lower eczema risk in 2-year-old children with the consumption with the consumption of organic dairy products [22]. Moreover, according to the results of the mentioned study organic dairy consumption resulted in higher CLA levels in breast milk of mothers [34]. However, the study found no association between atopic outcomes in children and overall organic vs. conventional diet [22].

### 3.2. Lifestyle studies

According to Rembiałkowska et al. [30] consumers of organic food assessed their health status significantly better than consumers of non-organic foods. However, apart from

the organic diet, this might also have been related to some other aspects of consumers' lifestyle (e.g. nutritional pattern, living conditions, physical activity, ways to manage stress etc.). Recent Dutch study [31] investigating the perceived health effects experienced by 566 consumers of organic food pointed out that the switch to organic diet is often accompanied by the use of more freshly prepared foods and other significant lifestyle changes. According to the mentioned study 70% of respondents experienced positive health effects of organic foods. They reported *i.e.* better general health, including feeling more energetic and having better resistance to illness (70%), a positive effect on mental well-being (30%), improved stomach and bowel function (24%), improved condition of skin, hair and/or nails (19%), fewer allergic complaints (14%) and improved satiety (14%).

At the same time results of the recently published Nutrinet-Sante´ Cohort Study [32] on more than 54,000 French adult participants show that regular consumers of organic products exhibit specific socio-demographic characteristics and an overall healthy profile. The authors suggest that this should be accounted for in further studies analyzing the health effects of organic food intake.

Even though the mentioned studies' design does not permit direct conclusions on health effects of organic foods, they provide new insight into the experienced health status of organic food consumers and their lifestyles and can serve as a basis for generating new hypotheses related to the organic diet, lifestyle and health.

### 3.3. Exposure to pesticides

As already mentioned, incidence of pesticide residues in organic plant based foods has been found to be at least four times lower compared to conventional foods [3]. In case of fruit, the difference in incidence between organic and conventional samples seems to be even greater [3].

Moreover, there is scientific evidence that dietary exposure of children to organophosphorus pesticides, measured as the level of pesticide metabolites in urine, is much lower on organic compared to the conventional diet [29]. It can be concluded that consumption of organic foods provides protection against exposure to organophosphorus pesticides commonly used in agricultural practices [28]. Even though the mentioned studies on children exposure to pesticides were not designed to assess the link between the urinary pesticide levels and their clinical effects, the negative health impacts of pesticides are well proven [11]. Some of them have been described to exert genotoxic, carcinogenic, neuro-destructive and allergenic effects[35]. Other act as strong endocrine disruptors [36].

### 3.4. Bioavailability studies

As previously stated, organic foods are, on average, characterized by significantly higher concentrations of antioxidants (*i.e.* phenolic compounds) than their conventional comparators [3]. Many of these compounds have been linked to a reduced risk of chronic diseases, including cardiovascular disease, neurodegenerative diseases and certain cancers [37]. However, it has also been pointed out that the contents of nutrients and secondary metabolites in plants cannot be directly translated into their health effect. First of all, these would be influenced by the level of actual absorption depending on a number of factors, such as e.g. the amount of promoters and inhibitors present in the food. In order to estimate the uptake of antioxidants, studies on their bioavailability as well as extensive research on their effects on specific physiological markers are necessary.

Two small single-meal studies measured the postprandial effect of organic and conventional apples and red wine on biomarkers for redox-processes [24, 25]. Neither of the studies found any difference in redox markers between organic and conventional products. In two other research studies, volunteers were presented either organically or conventionally produced tomato purée or carrots in addition to their habitual diet for 2–3 weeks [23, 38]. In the first study [23] no effect on haematological parameters, vitamin C and E in plasma, or LDL oxidation was observed. Carrot consumption as such had also no significant effect on the total antioxidant status of plasma. Plasma lutein increased significantly in volunteers consuming organic carrots. In the second study [38] respondents were fed organic or conventionally produced tomato purée for three weeks in a parallel design. No differences in bioavailability of β- carotene, lycopene or vitamin C from different tomato purées were observed. It should be underlined that the individual products were presented to the volunteers in addition to their habitual diet, which might have diluted the effect of production methods. In order to avoid such dilution, controlled studies comparing the effects of complete diets based on organic versus conventional raw materials are necessary.

One of such studies intended to compare the effects of organic versus conventional Mediterranean diet given for two weeks to 10 healthy men on their plasma antioxidant status [26]. The results indicated higher antioxidant plasma status of volunteers following the organic compared to the conventional diet. In the same study antioxidant activity was measured in a number of foods (*i.e.* fruit, vegetables, wine and milk). In most cases the antioxidant activity was higher in organic compared to conventional products. Another controlled dietary intervention study included 16 male and female volunteers given organic and conventional diet in a randomized cross over design for 2 × 3 weeks [27]. In both groups of patients the intake and excretion of flavonoids as well as the plasma concentration of selected oxidative defense markers was measured. The organic diet resulted in higher urinary excretion of kaempferol and quercetin, but no difference was observed between the diets in respect of the other flavonoids excretion. Most of the analyzed markers of antioxidative defense did not differ between the experimental diets. However, organic diet resulted in an increased protein oxidation and a lower total plasma antioxidant capacity compared with the conventional diet. The weakness of this study was that many of the plant crops used as the components of the organic and conventional experimental diets represented different crop varieties. Therefore it cannot be concluded whether the observed outcomes resulted exclusively from the differences in the production method, or were affected by the plant varieties.

### 3.5. Organic foods and cancer

There is strong scientific evidence for health benefits associated with increased consumption of crops rich in phenolics and other plant secondary metabolites with anti-

oxidant activity (e.g. carotenoids and vitamins C and E) [39-41]. Results of epidemiological studies have shown that high consumption of fruit and vegetables is associated with the prevention of chronic non-communicable diseases and certain cancers [42]. Various common fruit have been proposed to exert antimutagenic and anticancerogenic effects basing on their ability to induce cell cycle arrest and apoptosis[43, 44]. Recent reports on the relationship between food bioactive compounds and their anticancer effect in humans have been published by Faria et al. [45], McDougall et al. [46], Zhang et al. [47] and Ford et al. [48]. Analyzing the health benefits of foods researchers mainly focused on products derived from conventional farming. Results of these studies indicate that vitamins and certain phytochemical antioxidants including flavonoids (flavones, flavonols, flavanones, catechins, anthocyanidins) and carotenoids are effective against the proliferation of human colorectal, breast and stomach cancer cells [49-52]. What is more, as already mentioned, negative (*i.e.* carcinogenic) effects of cadmium and pesticide residues found more frequently in conventional products are also well proven [9-11]. On the basis of the above statements one could expect potent anticancer properties of organic compared to the conventional foods. Recently published results of the first big scale human cohort study to examine the association between the consumption of organic food and the risk of cancer have shown lower incidence of non-Hodgkin lymphoma in the population of organic *vs.* conventional food consumers [21]. Even though the above mentioned study did not find significant relation between organic diet and other types of cancers, it undoubtedly sheds new light on the topic of the health effects of organic foods.

### 3.6. Organic foods in pregnancy

Consumption of plant foods, including vegetables, is recommended to all pregnant women. Recently published results of the prospective Norwegian cohort study show that choosing organically grown vegetables may yield in additional benefits [53]. The aim of the study carried out in 2002-2008 on more than 28 thousands nulliparous pregnant women was to examine association between organic food consumption during pregnancy and the risk of preeclampsia. The authors found no association between preeclampsia risk and high intake of organic fruit, cereals, eggs or milk, as well as combined index reflecting organic consumption. However, women who reported to have eaten organic vegetables 'often' or 'mostly' had significantly lower risk of preeclampsia compared to those who reported 'never' or just 'sometimes'. The lower risk associated with high organic vegetable consumption was evident also when adjusting for overall dietary quality, assessed as scores on a healthy food pattern [53]. Authors of the study suggest that association between preeclampsia and use of organic vegetables could be related to decreased exposure to pesticides, changed exposure to secondary plant metabolites and/or influence on the composition of the gut microbiota.

## 4. Summary

Findings of human intervention studies on the health effects of organic foods carried out so far are very ambiguous. On the basis on the available data no indisputable conclusions can be drawn. However, big scale epidemiological studies of human population showing negative association between organic food consumption and risk of skin allergies, as well as the recently published outcomes of a large scale human cohort pointing on the relation of organic diet with lower incidence of non-Hodgkin lymphoma, shed new light on the topic of the health effects of organic foods. As research results on this topic can undoubtedly count on high societal interest, more comprehensive, well designed observational studies and human interventions are needed.

## 5. References


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