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# The Quality of Organically Produced Food

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Additional information is available at the end of the chapter

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## 1. Introduction

Organic farming began to develop in the modern world as a response to intensified farming and industrial agriculture, using synthetic fertilizers, chemical pesticides, introduction of monocultures into large areas, the separation the animal husbandry from plant production and using heavy machinery. All of this leads both to environmental degradation, and on the other hand, the overproduction of food. At the same time the food quality decreases continuously with regard to nutritional value, which is also the effect of strongly developed food technology.

Regulations specifying the conditions of organic crop and animal production are very strict, which results in high quality of agricultural products. The same applies to the processing scheme, however the techniques are not regulated so far (only few ones, such as radiation and genetic modifications, are banned in organic food processing). While conventional processing is based on several hundred different types of food additives (colorings, stabilizers, enhancers, etc.), the organic food processing allows only few dozen of additives, which usually are natural substances. This is a particularly difficult situation for organic farmers, who are obliged to maintain the quality of their products without using chemicals. However, the consumers' health is essential.

## 2. Food quality

The quality of food products is a subject of many debates, which result in different definitions of this term. The definition of food quality is constantly changing. Initially it was represented by the quantitative/measurable parameters. Nowadays more and more popular is

the holistic approach to the problem of quality. Vogtmann (1991) adopted a food quality evaluation approach including analytical and holistic criteria. According to this approach, the organic food quality assessment should be focused on all aspects and from all possible points of view, i.e. holistic model. Kahl et al., (2010a) analyzed the current status of organic food quality in relation to potential quality claims. They concluded, that a model is missed, which can be applied in scientific research as well as in practice. Furthermore they identified a gap between consumer expectations on the quality of the food and what can be guaranteed by regulation so far. Recently Kahl et al., (2012) published a model for organic food quality, taking into account a conceptual background which consists of the different (historical) sources as IFOAM standards, EC-Regulations and consumer understanding. A central part of this model is the evaluation, which should take part on different levels. As an essential part, organic food quality consists of product and process related aspects, which can be described by criteria and measured by parameters. This holistic or systemic view brings all different criteria together: technological value, nutritional value, sensory value as well as biological value and ethical indicators.

The technological value refers to the distinctive features of food products in light of the requirements of different interest groups. For individual participants of the food production chain (producers, processors, distributors and consumers) different features may be the most important distinguishing parameters, depending on the specific purpose for which the food product is intended.

The sensory quality is represented by a set of features assessed by humans by the use of standardized tests, based on human senses: taste, smell, touch, vision and hearing. Among these criteria, the appearance plays an important role in the assessment of raw materials and finished products, along with other organoleptic characteristics such as taste, smell or texture. Sensory quality is of great importance because it affects the process of making a choice when buying food. Sensory evaluation of food products is based on two main methods. The first one is to assess the desirability, acceptance and consumer preferences assessed in so-called 'consumer tests'. The second method is to evaluate the product based on defined criteria and by a specially trained person (so-called 'sensory panel'). The results are analyzed statistically.

The nutritional value can be considered as the minimum content of food contaminants (pesticide residues, nitrates, heavy metals, etc.) at the optimum content of valuable ingredients (vitamins, mineral elements, protein, etc.)

Interestingly the quality of organic food is mainly measured by standard single compound detection through analytical methods. In order to follow the holistic view on agriculture, also the evaluation of the food should be more holistic than reductionistic. Kahl et al., (2010 b) discussed several approaches and methods for this purpose. The biocrystallization method seems to be most encouraging in this direction (Kahl et al., 2009, Szulc et al., 2010, Busscher et al., 2010a,b).

Another question, related to organic food quality is, how authentic the food is. Authenticity can be understood in two ways. First one is represented by the sense of product traceability,

when it is possible to verify whether the characteristics of the product actually correspond to characteristics that are attributed to him. For instance, research conducted to determine whether the products offered on the market as organic really come from organic production (Kahl et al., 2010b). Therefore, it is needed to find methods that would enable tracing of all "biography of the product" in a fast and simple way. It would be an efficient tool for controlling the products offered on the market. Here an European project, bringing several approaches together is currently working on this topic ([www.http://www.coreorganic2.org/Upload/CoreOrganic2/Document/Leaflet\\_AuthenticFood\\_2012.pdf](http://www.coreorganic2.org/Upload/CoreOrganic2/Document/Leaflet_AuthenticFood_2012.pdf)) and the second approach authenticity can be understood as a counterweight to the growing trend of food globalization. More and more people look for food from safe sources, produced locally by the well-known manufacturers. Nowadays, food is transported from long distances, from the place of production by the place of processing up to the point of sale. As a result, consumers look for products less intensively processed, derived from known safe sources such as buying locally and directly from the farmer. The average food transport route from the place of production to the place of consumption in America is approximately 2,000 km (Wilkins and Gussow, 1997). There are scientific studies showing that it is possible to satisfy the nutritional needs of consumers with the State of New York based mainly on food produced locally. On the other hand, local agriculture in this state disappeared almost completely, although most consumers of the State of New York evaluated the local varieties of vegetables and fruits better (Wilkins and Gussow, 1997). The active opposition against food globalization is represented by the movement called "slow food" - to support food production which is an alternative to "fast food".

The biological value defines the impact of food on human health. This criterion is based on the holistic approach to the food quality and on the belief that the knowledge of the chemical composition of foods is not sufficient to determine the relationship between the consumed food and the human health. At the same time health is understood not only as the absence of disease, but also as the well-being, fertility and vitality. So far, several scientific studies have been conducted with regard to this issue, but only on laboratory animals (mice, rats and rabbits). Due to many obstacles of a formal, logistic and economic nature, very few studies assessing the direct impact of organic food on human health have been carried out.

The ethical value of food quality comprise three aspects: the aspect of environmental impact, the socio-economic aspect and the farm animal welfare.

One of the main factors determining the quality of products is the quality of the environment. We can expect the best crop quality only where the air, soil, ground-and surface water meet the required quality standards. Legal regulations on organic farming does not provide specific guidance on the definition of the quality of the agricultural environment where organic production can take place. However, the guidelines elaborated by various associations of organic farming may specify requirements in this field. Organic farmers are required to maintain the environment in good condition and should try to support the cycle approach. The organic production methods are focused on the protection of all environmental components against the pressure of the agricultural aspects. Environmental impact of organic and conventional farming was researched by Tyburski and Żakowska-Biemans (2007). The au-

thors point out that organic farming consumes less energy, which is of great importance. Nowadays, when the world is focused on energy crisis, organic agriculture achieves lower energy consumption rates because it does not apply fertilizers and pesticides, whose production requires high energy inputs. In addition, high energy lead to large emissions of greenhouse gases and the conventional farming is a very large emission source of them. Therefore, organic plant production significantly contributes to reducing greenhouse gas emissions. Furthermore, conventional agriculture leads to eutrophication and pollution of water resources, i.a. by the use of pesticides (Tyburski and Żakowska-Biemans, 2007). The biological diversity resulting from the spatial complexity of organic agricultural landscape supports three important functions: an ecological function, which is to maintain biological diversity and homeostasis; the production function, based on prevention, rather than fighting diseases and pests; and the function of the health and welfare, which results from the fact that humans are an integral part of the environment and can exist only through the harmonious coexistence with nature. Contact with nature is essential for mental health, and mental health is the foundation of physical health.

The choice of agricultural products, which are produced, processed and sold under conditions of equality and social justice is becoming increasingly popular among EU consumers. So-called “fair trade” principles implemented within developing countries are very important. By boycotting companies that do not follow the socioeconomic rules, the consumers may have a positive impact on reducing social inequalities, which are common in the production, processing and sale of agricultural products within tropical countries. Consumers have the choice because of the wide access to information about companies in the food trade market.

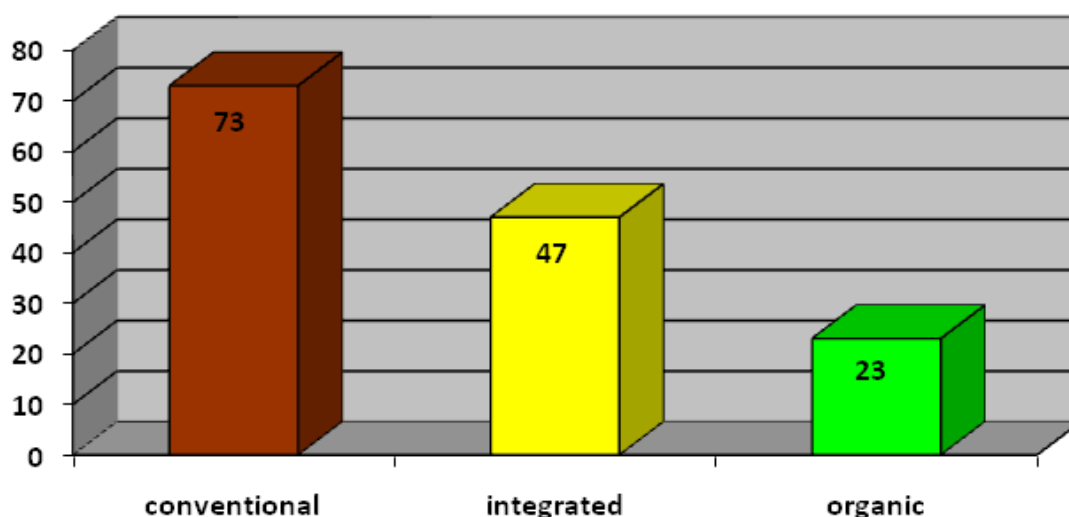
Furthermore, environmentally aware consumers are now more and more convinced that the methods of animal husbandry are important even during making decisions about purchasing food products. The reason is the suffering of animals, which is a result of very inappropriate conditions of animal husbandry (crowding, aggression, disease).

### 3. Plant products

#### 3.1. Harmful substances

Pesticides are a group of synthetic compounds which do not occur in nature, and are introduced into environment as a deliberate human decision. Use of pesticides can increase the profitability of crops, protecting them against pests and diseases. However, the applied chemicals do not affect only the target organisms. Their residues accumulate in plants and move along the food chain, including the human body. Depending on the dose consumed by a man with the contaminated food, the consequences include various health effects. In order to reduce the adverse impact of pesticides on human health, the Maximum Residue Limit (MRL) of pesticide, which may be present in food, has been established. MRL is usually established by testing of pesticides on rats. It is believed that the consumption of pesticides below the MRLs does not impose a health risk. However, pesticides even in low

concentrations are known or suspected to be the cause of many diseases and health problems including birth defects and cancer (BMA, 1992; Howard, 2005). The main problem is that the MRLs for pesticides are usually determined by testing of individual active substances (each one) on rats for a relatively short period of time. Almost nothing is known about the effects of consuming a total of potentially hundreds of different pesticides during the whole lifetime and associated actions resulting from synergistic mixtures of pesticides. This reaction is named in literature as a 'cocktail effect'. According to Howard (2005), the most recommended way to protect ourselves is to avoid consuming all of pesticides, especially in case of pregnant women, nursing mothers and young children up to 3 years. In 1994-1999 Baker et al., (2002) analyzed in the USA the fruit and vegetables from the three types of production (organic, integrated and conventional) for pesticide residues content. According to the results, the percentage of organic crops with a known presence of pesticide residues was approximately three times lower compared to conventional crops, and about two times lower compared to the raw materials from integrated agriculture (see Figure 1). Most samples with pesticide residues were found in conventional celery, spinach, pears and apples.



**Figure 1.** The comparison of contamination of agricultural crops with pesticide residues in the USA (in %) (Baker et al., 2002)

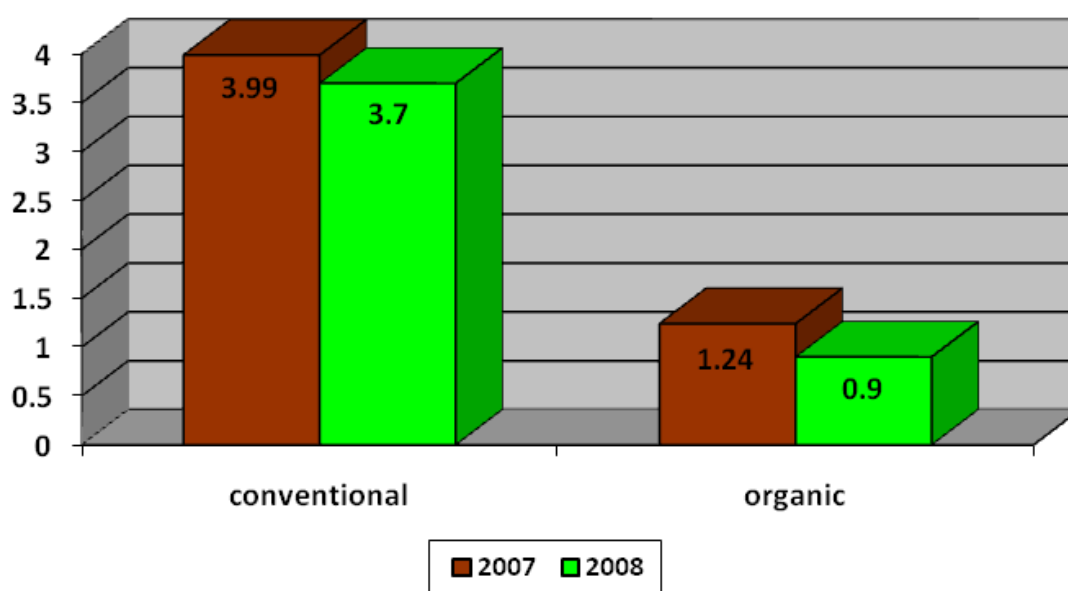
According to Lairon (2010), who reviewed the reports of French Agency of Food Safety and recent studies, from 94 to 100 per cent of organic foodstuffs contain no pesticide residues. In 1995-2001 similar survey was conducted in Belgium. The results revealed, that the percentage of organic crops contaminated with pesticides was 12%, whereas in the case of conventional crops this percentage reached 49% (AFSCA-FAVV, 2001). Research carried out in Poland gave a surprising result, as the highest percentages of crops containing pesticide residues were found in integrated agriculture, i.e. 47% (2005) and 48% (2006). Conventional agriculture presented the intermediate state between the other two management systems - 28% of raw materials in 2005 and 21% in 2006 contained pesticide residues. Crops derived from organic production were contaminated at a level of 5% (2005) and 7% (2006), which were the



lowest among all three systems. The detected residues of pesticides in organic fruits and vegetables result from its unauthorized use (Gnusowski and Nowacka, 2007), which indicates the imperfect control system of organic farms conducted by certification bodies. Such situations occur not only in Poland but in all countries worldwide. It should be noted that those cases are rare and in general organic raw materials present much lower pesticide residue level compared to conventional ones. Therefore, it is expected that a diet based on organic products should result in lower levels of pesticides in breast milk and human tissues. A few studies support this hypothesis. It was found in France that pesticide residues in human breast milk decreased significantly with increasing share of organic food (from 25% to 80%) in the daily diet of lactating women (Aubert, 1987). Similar results were obtained by comparing the content of organophosphorus pesticide residues in blood and urine of children fed organically vs. conventionally (Curl et al., 2003). Body fluids of children on conventional diet contained six times more pesticide residues than children on organic diet. These results indicate that consumption of organic products can significantly reduce the risk of excess pesticide intake with food and thus improve public health.

Each year the European Food Safety Authority (EFSA) publishes a report on monitoring of pesticide contamination in the market food in 27 European Union member states and two EFTA countries (Norway and Iceland). For several years, the report has also included the studies on organic food.

According to the report for 2007, the percentage of organic food products containing residues of pesticides at levels exceeding the MRL value was much lower than for conventional products. A similar result was obtained in 2008 (see Figure 2).



**Figure 2.** Samples with pesticide residues above the MRL in European food (%) (EFSA, 2009; 2010)

A number of studies clearly indicate a higher content of nitrates and nitrites in conventionally produced crops compared to organic ones. According to Lairon (2010) organic vegetables contain approximately 50% lower levels of nitrites when compared to conventional ones. This is the result of the treatment with synthetic, readily soluble nitrogen fertilizers, that is absorbed in large quantities through the root system and leads to accumulation of nitrates in the leaves and other plant organs. The organic system allows using organic fertilizers, which also contain nitrogen, but in organically bound form. When they reach the soil, followed by further decomposition of the fertilizer by soil microorganisms and by edaphon, the complex organic-mineral compound (humus) is formed. The plants get nitrogen from the humus only when they need it, so there is little possibility of excessive accumulation of nitrate in plant organs (Vogtmann, 1985). This is important for human health because the nitrates are converted into nitrites, which can cause a dangerous condition known as methemoglobinemia in case of infants, young children and older people (Mirvish, 1993). Furthermore, nitrite can react with amines to form carcinogenic and mutagenic nitrosamines, causing gastrointestinal cancers and leukemia (Szponar and Kierzkowska, 1990). This process is dangerous not only for children but also for adults of any age. Many authors compared the nitrate content in organic vs. conventional crops in the following species: white cabbage (Wawrzyniak et al., 2004; Rutkowska, 1999; Rembiałkowska, 2000), red cabbage (Rutkowska, 1999), potatoes (Hajslova et al., 2005; Rembiałkowska, 2000; Rembiałkowska, 1998), lettuce (Guadagnin et al., 2005), beetroot (Leszczyńska, 1996; Rembiałkowska, 2000), parsley (Rutkowska, 1999), carrot (Rembiałkowska, 1998; Rutkowska, 1999; Rembiałkowska, 2000), celery (Wawrzyniak et al., 2004), Pac Choy Chinese cabbage (Wawrzyniak et al., 2004). After averaging the results of the above studies and application of a formula by Worthington (2001):  $(\text{CONV-ORG}) / \text{ORG} \times 100\%$ , conventional crops contain an average of 148.39% more nitrate than organic crops. The highest levels of nitrate were found in red beetroots, because they exhibit the tendency of nitrate accumulation in roots. Therefore, despite their high nutritional value we should pay particular attention to the production system, as the best choice is the organic agriculture. The data presented above provide a basis to conclude that organic system helps to reduce the intake of nitrates and nitrites by the human body.

Heavy metals such as cadmium, lead, arsenic, mercury and zinc are introduced into the food chain from various sources: industry, transport, municipal waste and agriculture. For example, mineral phosphate fertilizers used in conventional agriculture can introduce cadmium into plant crops, as well as the metal industry and transportation cause cadmium contamination of soil and crops. Therefore, there are no clear differences in the heavy metal content between organic and conventional raw materials. Some of the studies confirm the higher levels of heavy metals in conventional crops, whereas other authors show the opposite results (Rembiałkowska, 2000). Problem to be solved is whether organic farming (composting, increasing of soil organic matter, increasing soil pH, etc.) can reduce the intake of heavy metals by crops.

Mycotoxins are toxic compounds produced by fungi of the groups of *Aspergillus*, *Penicillium* and *Fusarium*, which are found in food products (Kouba, 2003). Production of mycotoxins depends primarily on temperature, humidity and other environmental conditions. The ef-



fect of mycotoxins consumption on human health is negative, as they perform carcinogenic properties and affect negatively the immune system. More and more studies are currently carried out in order to compare the content of mycotoxins in food products, as the consumers are becoming more aware of aspects concerning food safety. The content of mycotoxins in organic products is discussed all over the world, as the use of fungicides in organic farming is prohibited. The most important question is whether the system of agricultural production has an impact on the development of mycotoxins. Studies comparing the mycotoxins content in organic vs. conventional products show comparable amounts in both types of products, sometimes indicating lower content of mycotoxins in organic products. Spadaro et al., (2006) and Versari et al., (2007) confirmed lower amounts of mycotoxins in organic products compared to conventional ones. Even if the level of mycotoxins in organic products is higher, the differences are small and do not exceed acceptable levels (Gottschalk et al., 2007; Jestoi, 2004; Pussemier, 2004; Maeder et al., 2007). According to Lairon (2010), organic cereals contain similar levels of mycotoxins as conventional cereals. An important case is wheat, which is a commonly consumed grain in European countries (mostly in the form of bread and pasta), and may be contaminated with mycotoxins. For this reason, much research is done to ensure the food security of winter wheat. The studies revealed that the level of damage caused by *Fusarium* and the concentration of mycotoxins were lower in case of organic crops. Environmental factors have comparable impact on the content of mycotoxins as the use of varieties with high resistance (Wieczyńska, 2010).

### 3.2. Bioactive substances

The nutritional value of food depends primarily on the appropriate content of compounds necessary for the proper functioning of the human body. The content of phytochemicals in plant foods is a major concern in the current food science. Secondary plant metabolites play a critical role in human health and may have a very high nutritional value (Lundegårdh and Mårtensson, 2003). Phenolic compounds are of particular interest because of their potential antioxidant activity and other healthy properties, including properties that may prevent cancer (Brandt and Mølgaard, 2001). Therefore the content of the secondary metabolites from the group of phenolic compounds in plant foods is of great interest, as more and more scientific studies are focused on comparing their content in organic and conventional products.

Secondary plant metabolites are substances naturally synthesized by the plant, but usually do not take direct part in the creation of its cells. They are usually produced as a reaction to exposure of the plant on the external stimuli, performing the functions of physiological changes regulators in case of pests attack or other stress factors (Brandt and Mølgaard, 2001). These substances include antioxidants, which protect the organism against the effects of many external factors and reduce the risk of civilization diseases (Di Renzo et al., 2007).

Plant secondary metabolites can be basically divided into compounds that do not contain nitrogen phenolic compounds, such as phenolic acids, flavonoids (six classes of them: flavones, flavonols, flavanones, flavanols, isoflavones, anticyanides) and terpenoids (e.g.

tetraterpenes, carotenes, xanthophylls) and nitrogen-containing compounds (alkaloids, amines, non-protein amino acids, glycosides, glucosinolates).

Mostly discussed are flavonoids, which constitute a large group of several thousand different compounds and play an important role in healthcare, performing many functions in the human body (Bidlack, 1998). Flavonoids present strong antioxidant activity, they chelate metals, affect the immune system e.g. by inhibiting tumor growth, prevent arteriosclerosis, strengthens blood vessel walls, reduce blood clot formation and thus reduce the risk of stroke, have a protective effect for vitamin C increasing its effectiveness; prevent some bacterial and viral infections (Bidlack, 1998).

According to Brandt et al., (2011), who conducted a meta-analysis of the published comparative studies of the content of secondary metabolites in organic vs. conventional crops, organic ones contain 12% higher levels of favorable secondary metabolites than corresponding conventional fruits and vegetables.

In most studies comparing organic vs. conventional raw materials with respect to the content of secondary metabolites, the total amount of polyphenols is analysed, with no breakdown for individual compounds belonging to this group. To express the content of polyphenols in the plant, the conversion can be used, such as tannic acid (Carbonaro et al., 2002). The content of flavonoids or flavonols themselves can be expressed as equivalent amounts of quercetin (Rembiałkowska et al., 2003a and b; Young et al., 2005; Hallmann and Rembiałkowska, 2006). Moreover, Anttonen et al., (2006) analysed the organic and conventional strawberries with respect to individual substances: quercetin and kaempferol belonging to flavonols. As a separate group of polyphenolic compounds, the anthocyanins are tested in plant foods by many authors (Rembiałkowska et al., 2003 b; Rembiałkowska et al., 2004; Hallmann and Rembiałkowska, 2006; Tarozzi et al., 2006). Polyphenol content is compared by some authors as a dry matter of the product. However in most cases the content in the fresh plant product is analysed. Anyway, all of the analyzed studies - except one (Anttonen et al., 2006), which showed lower levels of one substance (kaempferol) in organic compared to conventional strawberries - indicate a significant advantage of fruits (apples, apple juice, stewed apple, peaches, pears, blackberries, strawberries, frozen strawberries, red oranges) derived from organic production (Weibel et al., 2000; Carbonaro and Mattera, 2001; Carbonaro et al., 2002; Asami et al., 2003; Rembiałkowska et al., 2003a; Rembiałkowska et al., 2004; Weibel et al., 2004; Rembiałkowska et al., 2006; Anttonen et al., 2006; Tarozzi et al., 2006). After averaging the results of the above research and application of a formula by Worthington (2001):  $(\text{CONV-ORG}) / \text{ORG} \times 100\%$  organic fruits contain on average 44.7% more polyphenols than conventional ones.

The studies performed on vegetables are also conducted with respect to the total polyphenol content, with no breakdown for individual substances. The comparative research shows that organic vegetables (frozen corn, tomatoes, Pac Choi Chinese cabbage, lettuce, red peppers and onions) contain significantly more polyphenols than conventional vegetables (Asami et al., 2003; Rembiałkowska et al., 2003b; Young et al., 2005; Hallmann et al., 2005; Hallmann and Rembiałkowska, 2006). After averaging the results of the above research and application

of a formula by Worthington (2001):  $(\text{CONV-ORG}) / \text{ORG} \times 100\%$  organic vegetables contain on average 57.4% more polyphenols than conventional ones.

Carotenoids are another group of secondary metabolites of plants, characterized by strong antioxidative properties. They include over 600 pigments, which give the plants yellow, orange and red color. Carotenoids are also found in green leafy vegetables, but their color is masked by the green chlorophyll. The best-known carotenoid is beta-carotene found in many orange and yellow fruits and green leafy vegetables. Lycopene gives tomatoes intensive red color. Lutein and zeaxanthin make corn yellow. Carotenoids play an important role for human health, as they lower the blood cholesterol level, and thus favorably affect the heart. Moreover, they support the immune system - especially beta-carotene, which stimulates the increased number of lymphocytes. Carotenoids also exhibit antitumor activity, mainly thanks to its antioxidant properties (Stracke et al., 2008).

The comparative studies performed with respect to total carotenoid content in organic and conventional vegetables revealed the highest differences in case of pepper (Perez-Lopez et al., 2007). Slightly higher content of carotenoids (1.13%) was also found in organic tomatoes (Caris-Veyrat et al., 2004; Toor et al., 2006; Rickman Pieper and Barrett, 2009; Juroszek et al., 2009). The content of beta-carotene in organic carrots was higher, according to research by Abele (1987). By contrast Warman and Havard (1997) confirmed a lower content of beta-carotene in organic carrots. However, research by Caris-Veyrat et al., (2004) showed over 40% more beta-carotene in organic tomatoes.

The comparative studies conducted in the Organic Food Department of Warsaw University of Life Sciences confirmed significantly higher amount of beta-carotene in organic tomatoes and peppers (Rembiałkowska et al., 2003b; Hallmann et al., 2005; Hallmann et al., 2007), lutein in organic pepper (Hallmann et al., 2005; Hallmann et al., 2007) and total carotenoids in organic peppers (Hallmann et al., 2007; Hallmann et al., 2008; Hallmann and Rembiałkowska, 2008 a). However, higher lycopene content in organic material were found only in tomato juice (Hallmann and Rembiałkowska, 2008 b), whereas less lycopene in organic tomatoes and green peppers were found in comparison to conventional crops (Hallmann et al., 2005; Hallmann et al., 2007; Rembiałkowska et al., 2005; Hallmann and Rembiałkowska, 2007a and b; Hallmann and Rembiałkowska, 2008a).

The group of favourable antioxidants include also vitamin C, which performs fundamental metabolic functions in the human body. First of all it ensures the proper functioning of the immune system. Furthermore, it supports the biosynthesis of collagen, accelerates the process of wound healing and development of bones. In addition, it participates in the metabolism of fats, cholesterol and bile acids, regenerates vitamin E and other low molecular antioxidants such as glutathione and has a stabilizing effect in relation to the flavonoids. Vitamin C exhibits bacteriostatic properties and even bactericidal activity against some pathogens. It supports the absorption of non-haem iron and is involved in the production of red blood cells. Vitamin C inhibits the formation of carcinogenic nitrosamines, thus it reduces the negative effect of nitrate intake (Mirvish, 1993).

Except two studies, which confirmed lower vitamin C content in organic frozen corn (Asami et al., 2003) and organic tomatoes (Rembiałkowska et al., 2003b), most of the results revealed that organic crops were characterized by a higher content of vitamin C: spinach (Schuphan, 1974; Vogtmann et al., 1984), celery (Schuphan, 1974; Leclerc et al., 1991), kale (Schuphan, 1974), cabbage (Rembiałkowska, 1998; Rembiałkowska, 2000), lettuce (Schuphan, 1974), leek (Lairon et al., 1984), potatoes (Schuphan, 1974; Petterson, 1978; Fischer and Richter, 1984; Rembiałkowska and Rutkowska, 1996; Rembiałkowska, 2000; Hajslova et al., 2005), Swiss chard (Moreira et al., 2003), onion (Hallmann and Rembiałkowska, 2006), tomatoes (Rembiałkowska et al., 2003b; Rembiałkowska et al., 2005; Hallmann et al., 2005), pepper (Hallmann et al., 2005; Hallmann et al., 2007), apples (Rembiałkowska et al., 2003a) and oranges (Rapisarda et al., 2005). After averaging the results of the above research and application of a formula by Worthington (2001):  $(\text{CONV-ORG}) / \text{ORG} \times 100\%$  organic materials contain on average 32.2% more vitamin C than conventional products. Recent meta-analysis of the various vitamins in vegetables and fruits showed that the organic raw materials contained on average 6.3% more vitamins than conventional raw materials, but the difference was not statistically significant (Hunter et al., 2011).

Summary of studies comparing the mineral content in organic vs. conventional vegetables (Worthington, 2001) indicates a higher content of minerals (iron, magnesium and phosphorus) in organic crops. According to the author, a possible reason of a higher content of mineral elements in organic raw materials is associated with a higher content of microorganisms in organically cultivated soil. The microorganisms generate compounds that support plants in introducing active substances adsorbed by soil minerals, making them more available for plant roots. Recent meta-analysis of mineral content showed that organic fruits and vegetables contain an average 5.5% more minerals than conventional ones (Hunter et al., 2011), and the difference was statistically significant. This was found with respect to boron, copper, magnesium, molybdenum, potassium, phosphorus, selenium, sodium and zinc. According to Lairon (2010), organic plant products contain higher concentrations of iron and magnesium, which can be explained with abovementioned factors.

There are several studies confirming the higher content of total sugars in organic fruits and vegetables, including carrots, beets, red beets, potatoes, spinach, kale, cherries, red currants and apples (Zadoks, 1989; Rembiałkowska, 1998; Rembiałkowska et al., 2004; Rembiałkowska, 2000; Hallmann and Rembiałkowska, 2006; Hallmann et al., 2007). The higher sugar content is associated with higher technological quality (for instance in case of sugar beet) and also with the higher sensory quality (taste). In research carried out both by consumers and by the trained panel, vegetables and fruits produced organically are often better evaluated in terms of their sensory properties (Rembiałkowska, 2000). Numerous studies based on the food preferences were also performed on rats. The results revealed better sensory properties of organic materials (Maeder et al., 1993; Velimirov, 2001; Velimirov, 2002). Rats that were fed both with organic and conventional food presented the tendency to choose organic carrots (81% of animals) and organic wheat (68%). Smaller differences were found in the choice of apples and red beets from organic farming, which, however, were also more likely to be selected by more than half (58%) of rats.



Several studies carried out so far (Rembiałkowska, 2000; Worthington, 2001) confirmed lower total amount of protein in organic crops compared to conventional. However, the protein quality (considered as the content of essential amino acids) were found to be higher in organic crops. According to Worthington (2001), nitrogen derived from each type of fertilizer affect the quantity and quality of proteins produced by plants. A large amount of nitrogen available to plants increases the production of proteins, and reduces carbohydrate production. Furthermore, proteins produced in response to high levels of nitrogen, present lower amounts of essential amino acids, e.g. lysine, and therefore represent lower nutritional value for consumers.

The higher technological value of organic plant products results from higher dry matter content, so that organic products perform better storage quality (Bulling, 1987; Rembiałkowska, 2000). Samaras (1978) confirmed that the main impact on the amount of weight loss after storage of vegetables is the type of fertilizer applied to them. All tested root vegetables (carrots, turnips, beets and potatoes), which were grown with organic fertilizer were characterized by much lower storage losses. The higher storage losses of vegetables grown with mineral fertilizer may be associated with a higher content of water absorbed by the plant, along with easily soluble mineral compounds. The average storage losses of crops grown with mineral fertilizers were 46.4% of the initial mass, whereas in case of crops grown with organic fertilization the losses were 28.9% (Samaras, 1978). Bulling (1987) made a set of studies comparing the differences in the storage losses between organic and conventional vegetables and fruits. Average values for the organic raw materials tested in 53 different studies were found to be 10% lower than for conventional crops. These properties are important both from nutritional and economic point of view. The hypothesis that plant materials from organic production is better to store was also confirmed by Benbrook (2005). Higher dry matter content of organic raw materials were observed in carrots (Velimirov, 2005), apples (Weibel, 2004; Rembiałkowska et al., 2004), potatoes (Rembiałkowska, 2000), strawberries (Reganold et al., 2010). However, Gąstoł et al., (2009) found lower dry matter content of organic apples and black currant than in conventional ones.

#### 4. Animal products

Principles of organic animal husbandry refer to animal welfare (indoor farm density, access to open air, the presence of natural bedding, the possibility of movement), the nutrition (prohibition on synthetic feed additives) and rearing conditions (choice of breed, conditions of weaning and slaughter). Furthermore, organic livestock production is carried out without the use of antibiotics (except the situations, when the life of animal is endangered and there are no other therapeutic agents available), hormones, genetically modified organisms and their products. Organically reared animals can be fed only with organic materials.

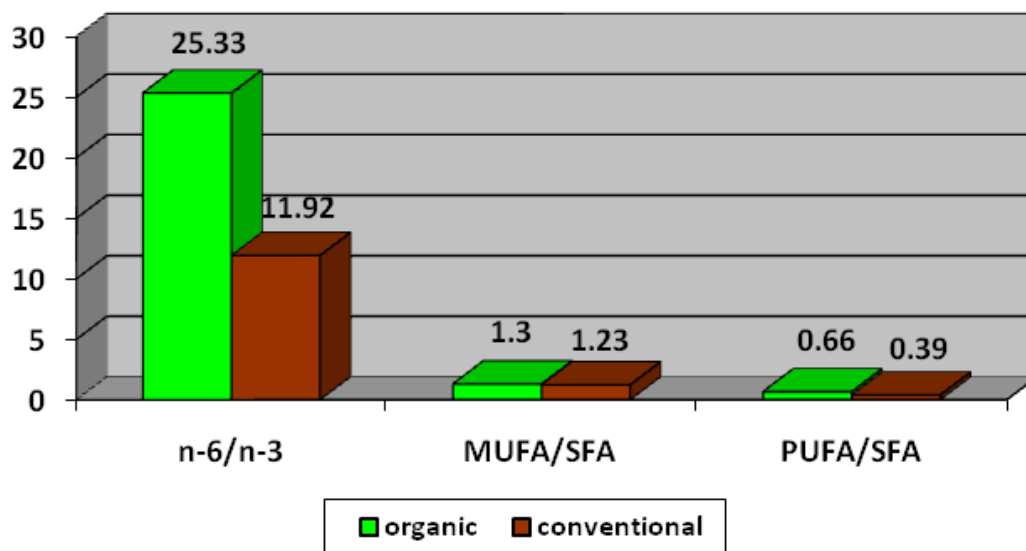
A key factor determining the quality of animal products is the animal feed, which in case of organic agriculture involves the use of seasonal grazing and cutting down on feed concentrates, which is beneficial for the content of bioactive substances in meat and milk.



#### 4.1. Meat

Meat derived from organic farming perform desirable nutritional properties, such as favorable ratios of fatty acids. This means the lower content of saturated and monounsaturated fatty acids, the higher content of polyunsaturated fatty acids, and a lower ratio of n-6 fatty acids to n-3 fatty acids. The meat produced organically exhibits also lower total fat content, which has been confirmed for: beef (Enser et al., 1998; Pastushenko et al., 2000), pork (Hansen et al., 2006; Bee et al., 2004; Nilzen et al., 2001; Kim et al., 2009), sheep (Fisher et al., 2000; Enser et al., 1998), lamb (Angood et al., 2007), poultry (Castellini et al., 2002). The studies conducted on poultry revealed different results, as higher content of saturated fatty acids was found in organic meat. However, it exhibited lower content of monounsaturated fatty acids and higher level polyunsaturated fatty acids. In turn, results obtained by Walshe et al., (2005) confirmed higher total fat content in organic beef, but comparable fatty acid composition in both types of meat. Research carried out on rabbit meat by Pla (2008) and Combes et al., (2003a) revealed a lower total fat content in meat derived from organically reared rabbits. However, Lebas et al., (2002) obtained opposite results.

Figure 3 below presents the comparison of fatty acid profile of *M. longissimus* muscle between organic and conventional pork derived from Korean black pigs (Kim et al., 2009).



**Figure 3.** Fatty acid profile of organic and conventional pork from Korean black pigs (Kim et al., 2009)

Most of the studies confirm a higher content of intramuscular fat in organic meat, which was found in beef (Woodward and Fernandez, 1999), pork (Sundrum and Acosta, 2003; Millet et al., 2004), mutton (Fisher et al., 2000). The higher intramuscular fat content is associated with better sensory quality of meat from organic production. Only research done by Olsson et al., (2003) indicated a lower content of intramuscular fat and a lower lean body mass in organic pork.

As far as sensory quality is concerned, the darker meat color was identified in the case of organic pork (Kim et al., 2009; Millet et al., 2004) and sheep (Fisher et al., 2000). Research conducted by Fisher et al., (2000) found that organic lamb meat is preferred much more than conventional because of the sensory properties. Castellini et al., (2002) demonstrated with the sensory profile that the organic poultry is more juicy and acceptable than conventional. According to Combes et al., (2003b), the organic rabbit meat is softer than conventional. The sensory assessment done by Pla (2008) confirmed that organic rabbit meat exhibited more liver flavor and less anise and grass taste.

The adverse properties of organic meat include the lower carcass weight (lower daily weight gains), which has been confirmed for beef (Woodward and Fernandez, 1999), pork (Sundrum and Acosta, 2003; Hansen et al., 2006) and poultry (Castellini et al., 2002). However, study performed by Millet et al., (2004) indicated a higher weight gains of organic pigs in comparison to conventional ones.

Organic meat is also characterized by poor storage quality (high levels of TBARS), which was confirmed by analyses conducted on beef (Walshe et al., 2005), pork (Hansen et al., 2006; Nilzen et al., 2001), mutton (Fisher et al., 2000) and poultry (Castellini et al., 2002).

## 4.2. Milk

Cow's milk is very variable with respect to fat content. This fraction is formed in about 95% by triacylglycerols, which are composed of fatty acids whose chain length and degree of saturation determine the nutritional value of milk fat. Saturated fatty acids are considered as a factor adversely affecting the human health, because they contribute to the development of arteriosclerosis (Pfeuffer and Schrezenmeir, 2000) and increased levels of blood cholesterol, which leads to cardiovascular diseases (Haug et al., 2007). Among the unsaturated fatty acids, the n-3 ones pose beneficial effects on the human organism. N-3 acids affect positively the nervous system, as well as they reduce the risk of diabetes and cardiovascular diseases (Horrobin, 1993; Hu et al., 1999). The important parameter of milk quality is also the ratio of unsaturated fatty acids n-6:n-3. If the content of the first group of acids is too high, the risk of inflammation, thrombosis, and autoimmune symptoms is increased. The most important fatty acid among the n-3 acids is alpha-linolenic acid (LNA), while linoleic acid (LA) occurs in the largest quantities among the n-6 acids. As for monounsaturated fatty acids, oleic acid is the predominant one, amounting to about  $\frac{1}{4}$  of the total weight of fatty acids. It supports the functioning of n-3 and n-6 acids, preventing them from oxidation, and lowers cholesterol and acts antineoplastic (Ip, 1997; Kris-Etherton et al., 1999; Mensink et al., 2003). A special place in the composition of cow's milk is conjugated linoleic acid (CLA). Cow's milk is the main source of the isomers of this compound in the human diet (Haug et al., 2004). The most important isomer (constituting about 90% of CLA) is *cis-9 trans-11*, preventing the development of cancer, heart disease and stimulating the immune system (Whigham et al., 2000). It is called rumenic acid because the rumen is the place of its synthesis from linoleic acid. Other CLA isomers (*trans-7 cis-9*, *trans-10 cis-12* and *trans-9 cis-11*) counteract obesity (by reducing fat and increasing muscle mass) and support the treatment of diabetes (Taylor and Zahradka, 2004). The content of CLA in milk fat is affected by a number of factors. First of

all, it depends on the feed given to animals (Parodi, 1999), followed by seasonal variations (Parodi, 1977), the endogenous synthesis of trans-vaccenic acid (TVA) (Grinari et al., 2000) and oxidation of linoleic acid (LA) during processing (Ha et al., 1989).

The research comparing the quality of milk from different production systems is based on the analysis of particular differences in the composition of fatty acids (Molkentin and Giesemann, 2007; Butler et al., 2008). According to the results of Ellis et al., (2006) organic milk can be characterized with a significantly higher content of polyunsaturated fatty acids, including n-3 acids (the difference in comparison to conventional milk was over 60%). The ratio of n-6: n-3 was consequently lower, which is favorable from a health point of view. Moreover, the amount of polyunsaturated fatty acids relative to monounsaturated ones was found higher. The detailed results are presented in table 1. Similar conclusions were also drawn by Butler and Leifert (2009) who confirmed that the value of the ratio of n-6: n-3 in organically produced milk does not exceed 1.25, while in the conventional milk is above 2.5.

% FA	Conventional milk	Organic milk
SFA	67,25 ± 3,54	68,13 ± 3,51
MUFA	<b>27,63 ± 2,94</b>	<b>26,19 ± 3,01</b>
PUFA	<b>3,33 ± 0,66</b>	<b>3,89 ± 0,61</b>
total n-3	<b>0,66 ± 0,22</b>	<b>1,11 ± 0,25</b>
total n-6	1,68 ± 0,46	1,68 ± 0,44
TVA	1,75 ± 1,09	2,06 ± 0,96
CLA	0,58 ± 0,34	0,65 ± 0,28

**Table 1.** Differences in fatty acid composition between organic and conventional milk (Ellis et al., 2006)

Qualitative changes in milk, resulting from the application of ecological production system, can be also identified in the concentration of CLA (Bergamo et al., 2003; Szente et al., 2006). A study by Butler et al., (2008) revealed that its amount may be higher by up to 60% compared to the content in the conventional milk. Research by Jahreis et al., (1996) confirms that the organic production of milk contributes to increased concentrations of CLA, TVA and LNA. This was also indicated by research by Chin et al., (1992), Lin et al., (1995), Prandini et al., (2001), particularly in relation to CLA content in cow's milk and buffalo milk. However, few studies showed no difference in the amount of CLA between milk from both production systems (Ellis et al., 2006; Toledo et al., 2002).

Antioxidants, especially vitamin E and carotenoids, are another advantage for the consumption of organically produced milk. Their content was found higher in milk from cows from organic husbandry and this corresponds to the fact that the feeding of such cattle is based on green forage pasture (Nielsen et al., 2004; Butler et al., 2008). This has been also confirmed by the research conducted within the project QLIF (Quality Low Input Food). The level of antioxidants in organic milk was almost double compared to conventional milk (QLIF, 2008).

Palupi et al., (2012) carried out a meta-analysis of comparative studies related to the nutritional quality of organic and conventional dairy products. The authors' approach used the Hedges' d effect size method with regard to the results obtained by various authors in the last three years. The meta-analysis confirmed, that compared to conventional dairy products, organic ones exhibit significantly higher content of protein, alpha-linolenic acid, conjugated linoleic acid, transvaccenic acid, docosapentanoic acid, eicosapentanoic acid and the total n-3 fatty acids. Furthermore, the n-3:n-6 ratio was found to be significantly higher in organically produced dairy products (0,42 vs. 0,23).

Organic production implies the abandonment of the use of mineral supplements, making the content of these components generally higher in conventionally produced milk. This has been confirmed by Coonan et al., (2002), who found the deficiencies of copper, selenium, zinc, iodine and molybdenum in the organic milk. Kuusela and Okker (2007) explain this as a result of a low content of trace elements in soil within organic farms. The use of synthetic fertilizers, which increase the concentration of macro- and microelements in soil are not permitted in organic farming. The crops, which have grown within such soil, are as a consequence a poor feed for animals with respect to these components, which contributes to their deficiency in milk. However, few studies showed a higher calcium content in organically produced milk (Lund and Algers, 2003; Zadoks, 1989).

Apart from the abovementioned benefits milk of organic production has one more advantage over the conventional milk. This is a prohibition on the use of antibiotics, which are often routinely given by conventional farmers to farm animals for the purposes of prevention. In the certified organic farms such practices are prohibited. The issue of the impact of antibiotics in conventionally fed cows on the resistance of the human body to these antibiotics is still a topic of discussion. The use of synthetic hormones and genetically modified feed ingredients is also not allowed in organic system. For this reason, the residues listed above, which are frequently detected in conventional dairy products, are negligible in milk from organic production. Research conducted by USDA (United States Department of Agriculture) confirmed this hypothesis by detecting the presence of pyrethroid pesticides in 27% of conventional milk samples. Among the organic samples, only one contained a low level of these substances, while others were completely free of these contaminants (Benbrook, 2005). The analysis of heavy metals in both types of milk showed no differences between the samples, detecting low contamination of all samples (Gabryszuk et al., 2008).

Sensory quality assessments of organic and conventional milk are very rare and so far inconclusive. Research by Zadoks (1989) showed greater acceptability of conventional milk among consumers. The predominant factor responsible for this result was the peculiar smell of cow's milk, much more intense in the case of organic milk. Today's consumers are not used to such properties, preferring generally available in the market milk with a neutral smell. Croissant et al., (2007) found that consumers felt more grassy and animal smell in milk derived from organic production compared to typical conventional milk, but only when the temperature of milk was 15°C. No differences between milk from both systems were found at a temperature of milk of 7°C. The authors concluded that there are clear dif-

ferences between the smell and quality of milk from organic and conventional systems, but this has no effect on consumer acceptance.

## 5. Conclusions

The favorable high nutritional value of food depends not only on the appropriate content of compounds necessary for the proper functioning of the human body and the low content of harmful substances. According to studies cited here, the nutrient content in plant raw materials in most cases is higher when they come from organic farming. This includes the compounds belonging to the desirable antioxidants: vitamin C, phenolic compounds, carotenoids, as well as sugars and dry matter. The latter two components both contribute to higher technological value and reduction of storage losses. Furthermore, they significantly increase the palatability of organic fruits and vegetables. As a result, the flavor of organic products may be more intense compared to conventional materials, so that consumers evaluate the taste of organic materials as more typical, characteristic of the plant, which is also confirmed by preference tests performed on animals.

In terms of pesticides and nitrates from the consumer point of view raw materials from organic production are certainly safer than conventional. The level of mycotoxins is dependent not only on the production system, but is also affected by storage and weather conditions. Studies show that there are no significant differences in the content of cereals with mycotoxins between organic and conventional products.

Meat derived from organically reared animals exhibit positive quality characteristics, such as favorable ratios of fatty acids and low total fat content. Organic meat is also better evaluated according to their sensory qualities, which is associated with a higher intramuscular fat content. The unfavorable properties of organic meat include lower carcass weight (lower daily weight gain), and inferior storage quality (high levels of TBARS).

Milk from organic production is characterized by a favorable fatty acid composition (including a high content of CLA), high levels of vitamins and antioxidants, acting an important part health-oriented prevention. However, due to the ban on the use of mineral supplements and fertilizers in organic farming, milk from organic production may be characterized by the deficiency of some macro- and micronutrients. Moreover, milk from organically reared animals can be worse evaluated by consumers because of the specific organoleptic characteristics, especially the smell.

According to Dangour et al., (2010) and Huber et al., (2011), the higher nutritional value of organic foodstuffs cannot be simply considered as an evidence, that consumption of organic food contributes to the improvement of consumers' health. Based on the research carried out so far, no clear relationship between nutritional value and health effects can be defined. Evidence for such effects are still lacking, therefore more developed studies are needed to determine the nutrition-related health effects that result from the consumption of organic products.



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