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Pesticide Residues in the Organically Produced Food

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1. Introduction

A basic aim of using chemical products for plant protection (pesticides) in farming is the quantity increase and quality improvement of agricultural crops. Pesticides are destined, inter alia, to control any kinds of pests, weeds, pathogenic organisms and other factors which cause plant damage. Therefore, the use of these substances, which have biocidal effects, is deliberately introduced on crops and get through them to people. In addition, a side effect of agrochemical treatments is their movement to the various components of the natural environment.

Therefore, considering the benefits of agriculture chemization, one should also take into account, inter alia, the risk associated with the presence of pesticide residues in commercially available agri-food products. Although modern chemical plant protection products are designed in such a way as to selectively affect specific pests, pest groups, fungi, or weeds, without impacting other organisms (including humans), and the requirements on the toxicological safety placed at their registration are very stringent, there is always a risk that human exposure to pesticide residues in food products may constitute a potential danger to health.

Risk assessment for the overall population and vulnerable populations (e.g. infants, children or pregnant women) takes place both at the stage of registration of the active substance, and subsequently in the monitoring and official food control. In the first case, this process involves a thorough evaluation of the results obtained in long-term toxicological tests on animals, *in vitro* and field studies. The result of this assessment is approval (or rejection) of the proposed MRL (Maximum Residue Level), identified on the basis of field studies in line with the Good Agricultural Practice, recommended by the manufacturer. In the second case, the risk assessment is carried out based on the results of research of the market products, while it is very important to conduct research properly – from sampling, through sample analysis in an accredited laboratory, to the result along with the associated uncertainty. In both cases, the essence of the risk assessment process is to compare the estimated, potential chronic and acute exposure to a pesticide (absorbed with food) with the designated reference values which are considered safe.

A global scale of acute poisoning by plant protection chemicals is not exactly known and all data are based on estimates. In 1973, the first time the World Health Organization reported that there were 500 thousand cases of such poisoning a year. However in 2002, the number of deaths due to acute poisoning by pesticides was estimated at about 220 thousand annually, which represents only a small percentage of the total number of such poisonings of roughly 26 million a year (Richter, 2002). The threat of the use of chemicals in agriculture is greatest in developing countries, since the awareness of the local population about the negative impact of pesticides on health is still relatively low. This is confirmed by recent research carried out in rural regions of Asia where the number of deaths due to pesticide poisoning is estimated at 300 thousand cases a year (Eddleston *et al.,* 2008).

However, not only acute poisoning is a dangerous result of the presence of pesticides in agricultural production. An equally significant threat is brought by chronic poisoning, which occurs only after a certain time, when the accumulation of substances in the body exceeds the acceptable level. Then, even low doses of pesticide absorbed by the body – when administered long enough – contribute to the highly toxic effects. Pathological changes the situation contributes to are often irreversible.

Pesticides have neurotoxic and immunotoxic effects as well as carcinogenic properties. Some of them have a chemical structure similar to human hormones, such as nonylphenol, an active substance of several pesticides. In terms of chemical structure, this compound is very similar to oestrogen, the most important female reproductive hormone. Nonylphenol may partly displace it from metabolic pathways, interfering with the reproductive cycle of females (Odum *et al.,* 1997).

A number of compounds, where it is demonstrated to affect the human endocrine system, remain in use in modern agriculture (Ansar Ahmed, 2000). These include herbicides such as atrazine, alachlor, simazine and trifluralin. Among these are the fungicides benomyl, mancozeb, maneb, metiram, viclozolin, zineb and ziram, and in the group of insecticides there are such active substances as cypermethrin, endosulfan, esfenvalerate, fenvalerate, kelthane, lindane, methomyl, permetrin (Ansar Ahmed, 2000).

It is believed that the plague of infertility, which in recent years has been recognized by WHO as a social disease (WHO, 2010), is caused, inter alia, by the presence of pesticides in agri-food production. Since the introduction of pesticides on the market, or roughly since the mid-twentieth century, we have observed a downward trend in terms of quantity and quality of the Europeans sperm. It is pointed out by Howard (2005), who as one of the reasons gives just the use of chemical pesticides, present in food. Infertility problem now concerns about 15-20% of all couples trying to conceive (WHO, 2010). The reason for such state are not only pesticides, because it probably consists of a variety of other factors, but the negative impact of pesticides is unquestionable (Howard, 2005).

In the body of every man there are certain amounts of chemical compounds that are brought by ingestion or inhalation. It concerns pesticides as well. It was proved by Gilman *et al.* (1997) by examining the contents of selected compounds in the blood plasma of women from circumpolar zone countries. It turned out that even in countries that are considered to be free from contaminants (such as Iceland and Greenland), human plasma is contaminated with compounds which are derivatives of DDT (see Figure 1 and Figure 2). This product was already withdrawn from use in the 70s of the twentieth century because of its toxic effects on human health. In the test samples there was also found the presence of other active substances of pesticides, such as chlordane, HCB and mirex, which is not irrelevant in determining the mechanism of toxicity of the mixture on the human body.

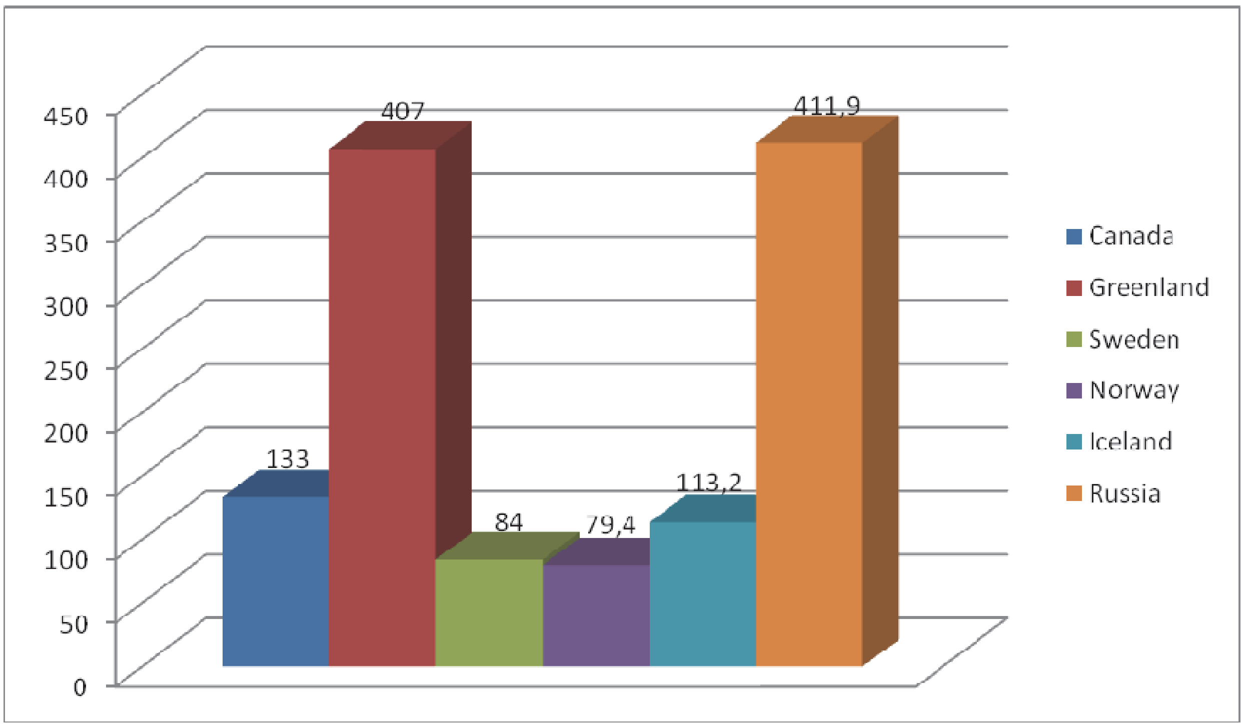


Fig. 1. The content of p,p′-DDE in the blood plasma of women (geometric mean μg/kg of fat) (Gilman *et al.*, 1997)

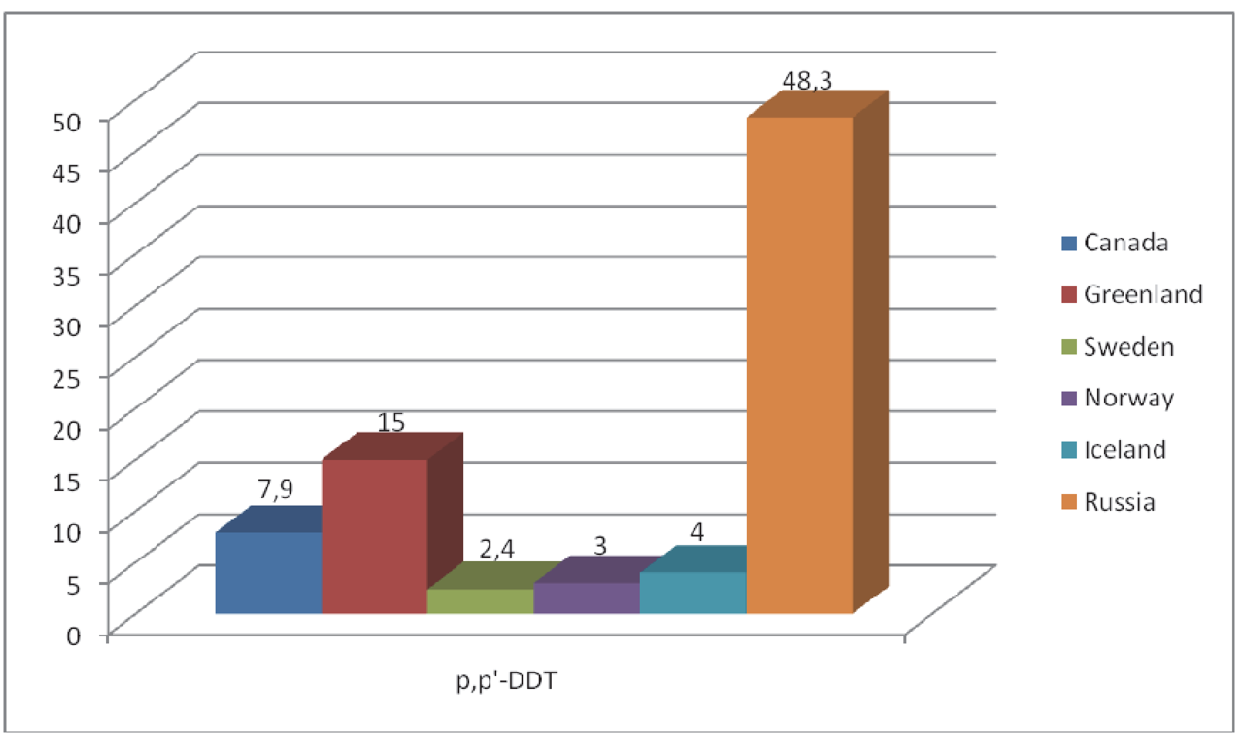


Fig. 2. The content of p,p′-DDE in the blood plasma of women (geometric mean μg/kg of fat) (Gilman *et al.*, 1997)

The exposure of children to poisoning by pesticides in fruit was the subject of the research by Pennycook *et al.* (2004) – they conducted a risk assessment of the health of British children on the basis of consumption of apples and pears. The result of their study was the number of children aged 1.5-4.5 years who are exposed to daily intake of pesticide in an amount that exceeds the maximum permissible value (ARD - acute reference dose). The analysis was carried out for the content of dithiocarbamates, phosmet, and carbendazim. Depending on harvest time and the type of tested compound, the results ranged from 10 to 226 children per day. There were therefore variable levels of pesticide residues, which sometimes reached values exceeding the ARD dose by six times.

2. Pesticides vs. organic farming

Against the background of pessimistic market research results in terms of food contamination by pesticides, a reasonable alternative appears to be the consumption of organic products. One of organic farming iron rules is to give up the use of agrochemicals, i.e. not only synthetic mineral fertilizers, but also chemical plant protection products. Such a system of agriculture is protected by law, which in addition to establishing policies requires regular inspection of the manufacturing process. In case of organic products, the European law does not define, however, other than the MRL values for conventional products and there are some products that are acceptable in organic system. They are presented in the list below (Commission Regulation (EC) No. 889/2008), and the products can be used only in case of threat to crop plant, provided that the products are used in accordance with the provisions established at Member State level.

i. Substances of crop or animal origin
   - Azadirachtin extracted from *Azadirachta indica* (Neem tree) – insecticide
   - Beeswax[1] - pruning agent
   - Gelatine – insecticide
   - Hydrolysed proteins[1] - attractant, only in authorized applications in combination with other appropriate products of this list
   - Lecithin – fungicide
   - Plant oils (e.g. mint oil, pine oil, caraway oil) - insecticide, acaricide, fungicide and sprout inhibitor
   - Pyrethrins extracted from *Chrysanthemum cinerariaefolium* – insecticide
   - Quassia extracted from *Quassiaamara* - insecticide, repellent
   - Rotenone extracted from *Derris* spp. and *Lonchocarpu* spp. and *Terphrosia* spp. – insecticide

ii. Micro-organisms used for biological pest and disease control
   - Micro-organisms (bacteria, viruses and fungi)

iii. Substances produced by micro-organisms
   - Spinosad – insecticide – only where measure are taken to minimize the risk to key parasitoids and to minimize the risk of development of resistance

iv. Substances to be used in traps and/or dispensers
   - Diammonium phosphate[1] - attractant, only in traps
   - Pheromones - attractant, sexual behavior disrupter; only in traps and dispensers
   - Pyrethroids (only deltamethrin or lambdacyhalothrin) - insecticide; only in traps with specific attractants; only against *Bactrocera oleae* and *Ceratitis capitata* Wied.

v. Preparations to be surface-spread between cultivated plants
   - Ferric phosphate (iron (III) orthophosphate) – molluscicide

vi. Other substances from traditional use in organic farming
   - Copper in the form of copper hydroxide, copper oxychloride, (tribasic) copper sulphate, cuprous oxide, copper octanoate - fungicide; up to 6 kg copper per ha per year; for perennial crops, Member States may, by derogation from the previous paragraph, provide that the 6 kg copper limit can be exceeded in a given year provided that the average quantity actually used over a 5-year period consisting of that year and of the four preceding years does not exceeded 6 kg
   - Ethylene[1] - degreening bananas, kiwis and kakis; degreening of citrus fruit only as part of a strategy for the prevention of fruit fly damage in citrus; flower induction of pineapple; sprouting inhibition in potatoes and onions
   - Fatty acid potassium salt (soft soap) – insecticide
   - Potassium aluminium (aluminium sulphate) (Kalinite)[1] - prevention of ripening of bananas
   - Lime sulphur (calcium polysulphide) - fungicide, insecticide, acaricide
   - Paraffin oil - insecticide, acaricide
   - Mineral oils - insecticide, fungicide; only in fruit trees, vines, olive trees and tropical crops (e.g. bananas)
   - Potassium permanganate - fungicide, bactericide; only in fruit trees, olive trees and vines.
   - Quartz sand[1] – repellent
   - Sulphur - fungicide, acaricide, repellent

vii. Other substances
   - Calcium hydroxide - fungicide; only in fruit trees, including nurseries, to control *Nectria galligena*
   - Potassium bicarbonate - fungicide

[1] In some countries the product is not categorized as a plant protection product.

Although at first glance the above list seems to be quite large, from a practical point of view only few of the plant toxic pesticides are currently in widespread use - pyrethrin, rotenone or neem. Pesticides containing natural toxic substances of plant origin have the capacity for rapid biodegradation. Pyrethrin in most cases decomposes in 24 hours – this time can extend up to 2 days. Rotenone is in turn more stable in field conditions, the degradation takes several days to a week. What is more, they are generally used in relatively low doses - for comparison, organophosphate insecticides, used to control virtually the same groups of insects, must be applied in amounts of 50-fold or even 100-fold. Not to mention that their biodegradation may take up to several months (Benbrook, 2004).

A very effective bioinsecticide, authorized for use in organic farming as well, is spinosad. Application of this compound involves the risk of residues of the active substance in cultivated raw materials. In 2001, one of the orchards used the pesticide for 31% of nectarines - its residues were found in 13.5% of samples tested. However, the contents were found to be very low, at levels from 0.006 to 0.029 ppm. You need to have in mind the low toxicity of spinosad for mammals, and therefore the health risk in case of such cultivated fruit is negligible (Benbrook, 2004).

The above-described biological plant protection products, authorized for use in organic farming, however, should occupy a secondary place on such farm. The idea of organic farming is based in fact mainly on preventing the emergence of diseases and pest infestation. This can be achieved by methods that do not interfere with the natural environment and pose no threat to humans. The first way is the right crop rotation, properly matched to habitat, and economic and organizational conditions of farm (Jończyk, 2005). It allows the maintenance of high biological activity of the soil, reducing the stroke of crops by specific diseases and pests which chemical control is difficult or impossible. Frequent cultivation of the same or related plant species after each other always increases their infection by specific diseases (crop rotation diseases) which are transferred to the subsequent crop through soil and crop residues, such as stem base disease of cereals, fusariosis of many plant species, Cercospora beticola and beet necrotic yellow vein virus (BNYVV) etc., and pests, such as golden nematode and sugarbeet nematode, *Haplodiplosis equestris* etc., and their chemical control is expensive and often little effective. Furthermore, such rotation reduces intensity of onerous weed species. Each species of crop plants is accompanied by a group of weeds which the rhythm of growth and development are similar to cultivated plants. Therefore, frequent comeback of the same or related plant species to a field leads to the compensation of certain weed species.

Another way of prevention used in organic farming is the development of biodiversity on the farm. This goal is achieved through proper diversification of the landscape, which exerts a strong influence on species richness. The area surrounding the fields, woodlots and water reservoirs that are left in a position similar to the natural represent the ecological corridors and habitats for many groups of organisms, including those useful. These include species of natural enemies of pests – thanks to them the number of organisms onerous for farmers, which in a conventional farming system are controlled by pesticides, may be limited. This is demonstrated by numerous studies confirming, inter alia, a significantly higher density and more species of ground beetles (*Carabidae*) in organic farming (Kromp, 1989; Irmler, 2003).

3. The presence of pesticide residues in organic products

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 3).

In 2007, a total of 2,980 organic products were tested. The largest group consisted of fruit and vegetables, while others included cereals and processed products. The percentage of samples containing residues of pesticides in each group is shown in Figure 4.

In 2008, there were tested 3,131 organic products in total. The largest group also represented fruit and vegetables, and other cereals and processed products included baby food as well. The percentage of samples containing residues of pesticides in each group is presented in Figure 5.

In the 90s of the twentieth century, Baker *et al.* (2002) conducted a broad study of pesticide residues in food from different sources in the U.S. These sources were classified into three groups - organic, conventional and integrated (intermediate between the other two.) The study proved conclusively that the slightest pesticide contamination occurred in organic production – in this case the percentage of such samples was more than three times lower than in conventional production, taking into account fruit and vegetables separately as well as all fresh food. For the analysis there were used three different test programs, each of which confirmed the studied tendency. These studies concerned the years 1993-1999 and then were continued for three consecutive years by the USDA. The additional studies

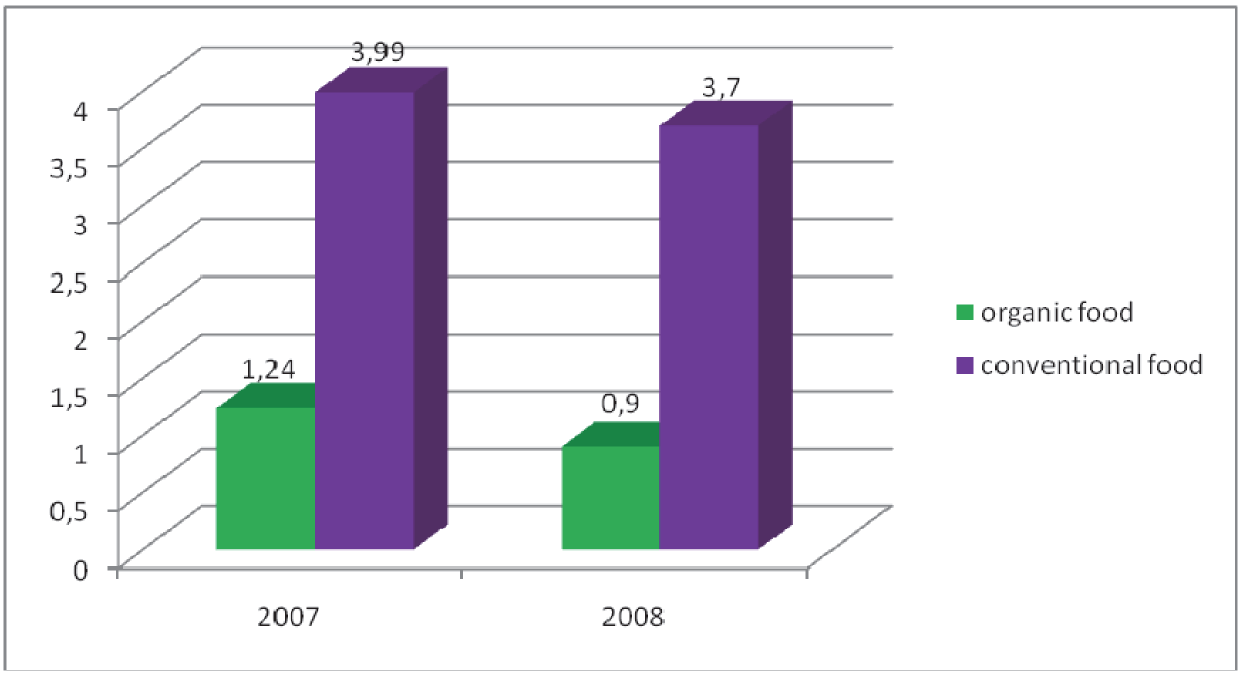


Fig. 3. Samples with pesticide residues above the MRL in European food (%) (EFSA, 2009; 2010)

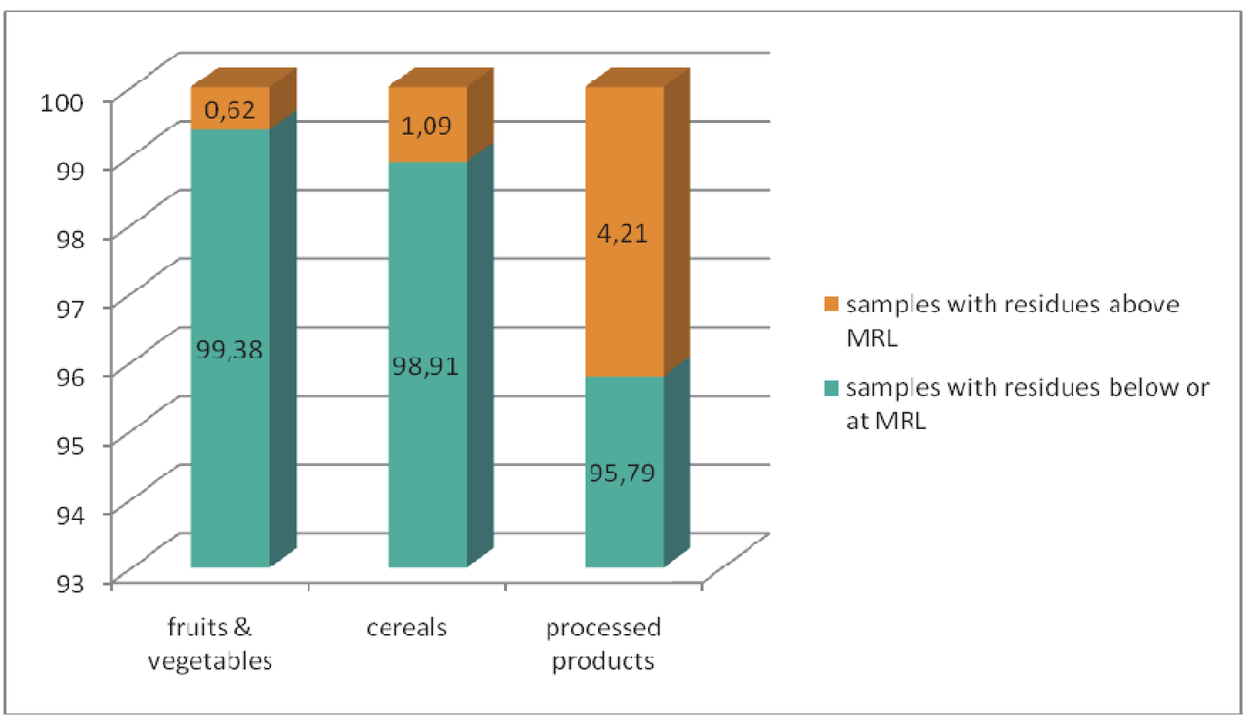


Fig. 4. The percentage of organic food samples containing residues of pesticides below and above the MRL in 2007 (EFSA, 2009)

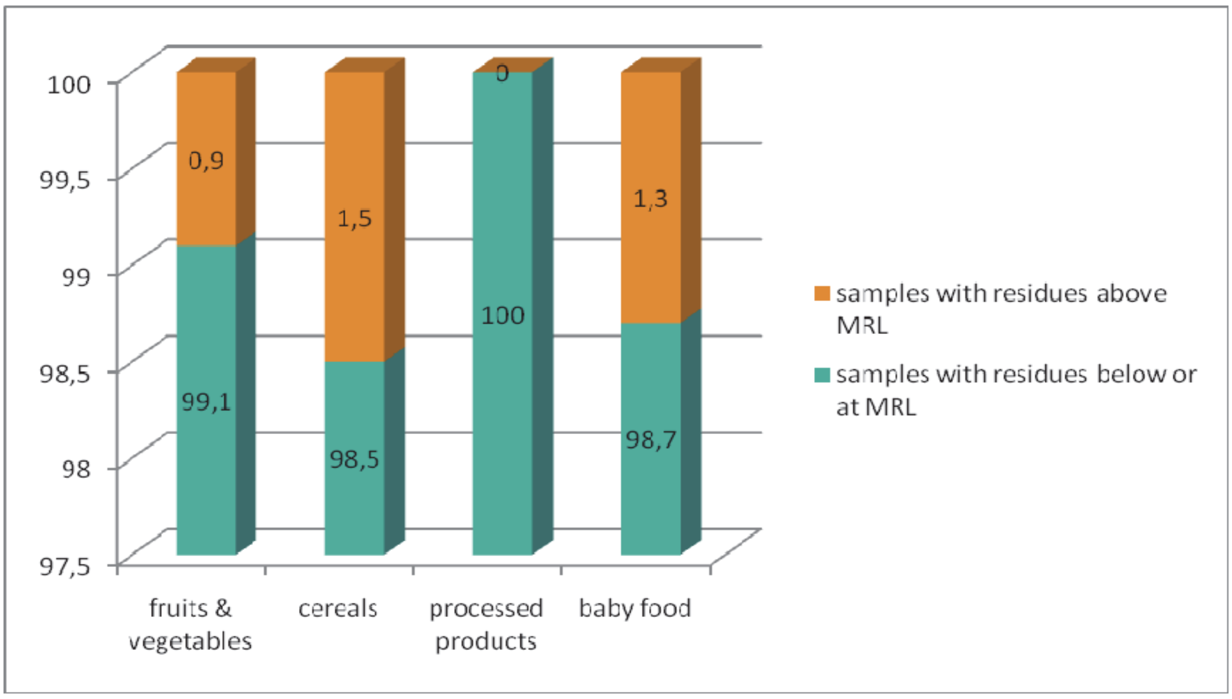


Fig. 5. The percentage of organic food samples containing residues of pesticides below and above the MRL in 2008 (EFSA, 2010)

took into account more than twice as many samples of organic fruit, which allowed the increase of statistical confidence of comparing the quality of conventional and organic products. Full results of the tests conducted are shown in Figure 6. These results do not take into account the samples with residues of organochlorine (OC) pesticides, because they are

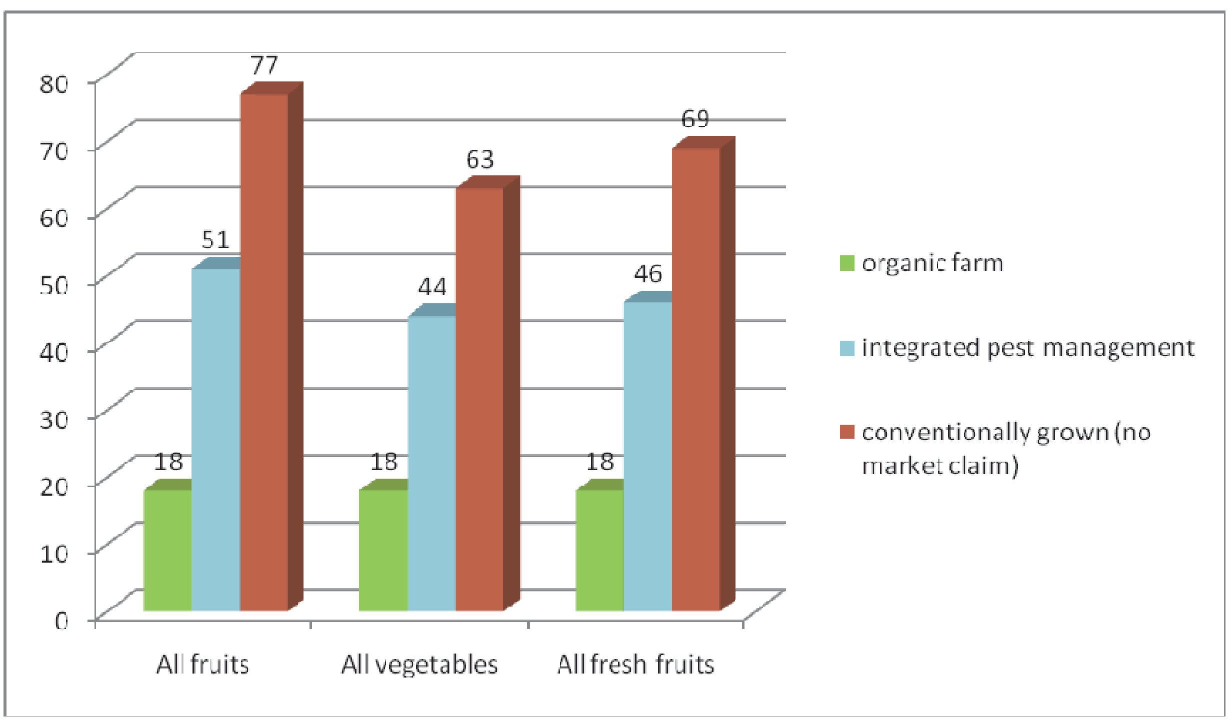


Fig. 6. Frequency of pesticide residues in fresh fruits and vegetables by market claim 1993-2002 (%) (Benbrook, 2004)

no longer allowed in any of the production systems, even conventional one. Excluding them from the analysis, there was obtained a more reliable picture of the management of plant protection products in the modern agriculture.Within 10 years, when the study was conducted, the probability of residues of at least one pesticide in conventional vegetables proved to be 3.5 times greater than for organic vegetables. Another interesting conclusion is that a consumer who buys from 1 to 2 kg of conventional peaches in the supermarket has more than 11-fold greater chance that they will get the fruit containing residues of seven pesticides at least than the chance to buy peaches completely deprived of such impurities. It is also much more possible that a person buying celeries will get raw materials containing at least five different pesticides, rather than they will buy celeries with the residue of one chemical agent at most (Benbrook, 2004).

Among conventional raw materials, the highest level of pesticide contamination was typical for such vegetables as spinach and celery, and fruit, such as apples and pears. One should keep in mind that the number of food samples from organic production was much lower (even after the addition of research in 2000-2002) than in case of the other two groups, and therefore the conclusions on the degree of exposure, depending on the species of organic fruit and vegetables, cannot be drawn.

In Sweden, there were also conducted comparative studies of three types of production (The Swedish Monitoring, 2003; 2004; 2005), and the proportions in the results were similar. However, there should be noted the scale in case of the percentage of contaminated food in the U.S. and Sweden. In the United States, pesticide residues were present much more frequently, respectively in each of the analyzed groups (see Figure 7). This difference may result from slightly different principles of organic farming and control on both continents. The approach towards agriculture in the U.S. and Europe is diverse as well. The discrepancy may stem from the difference in the functions of agriculture and rural areas, there is another

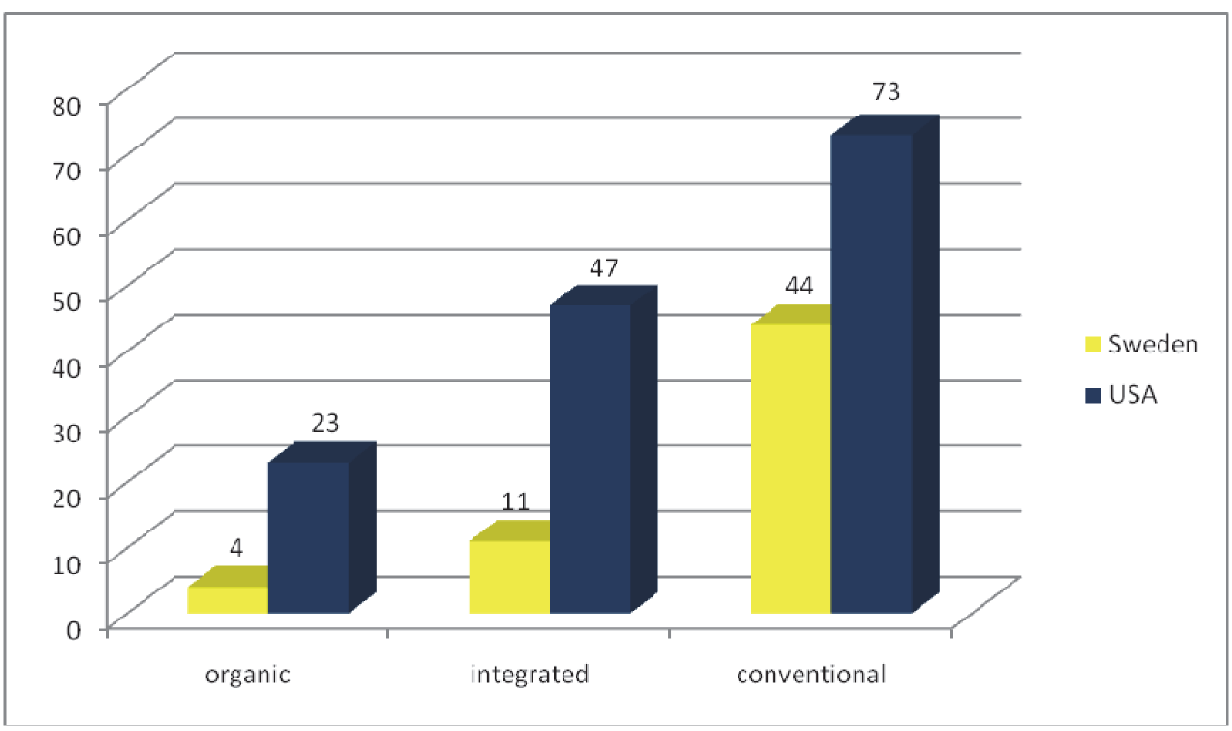


Fig. 7. The scale of contamination of agricultural crops with pesticide residues in the U.S. and Sweden (Baker *et al.*, 2002; The Swedish Monitoring, 2003; 2004; 2005)

definition of farm as well as parameters determining its performance. In Europe, a prosperous farm is considered to be one that achieves a high yield per hectare and high efficiency of livestock production. However, in the United States, a criterion for success is the profit from the dollar invested, i.e. so-called ROI (Risk on Investment). In a situation where there is a possibility of increasing the profitability of production (such as pesticide use), any fears of risk of using such solutions recede into the background. The attitude towards agricultural production, different than in Europe, contributes as well – less and less agricultural land is in private hands, and an increasingly important role in land use is played by corporations. The approach to agriculture is therefore less emotional and more economical (Nowak, 2004). Therefore, in the United States pesticides are used much more widely, which also has an impact on organic farming, since, as it is known, compounds move in the environment.

The Belgian studies conducted in 1995-2001 (AFSCA-FAVV, 2001) were of a similar nature, except that the integrated production was not taken into account. The raw materials of organic food contained pesticide residues in case of 12% of samples, while the conventional product rate reached 49%.

The UK also carried out a comparative study of the conventional market food vs. organic one. The share of samples contaminated with pesticides in different food groups is presented in Figure 8.

According to the results of these studies, the likelihood of the presence of pesticide residues in conventional infant food was 7-fold greater than in the organic products. Very large differences were also observed in case of fruit (more than 7-fold higher percentage of contaminated conventional samples compared to organic ones) and grains (there were no residues in a single organic sample, while in the conventional group the contamination comprised 42%).

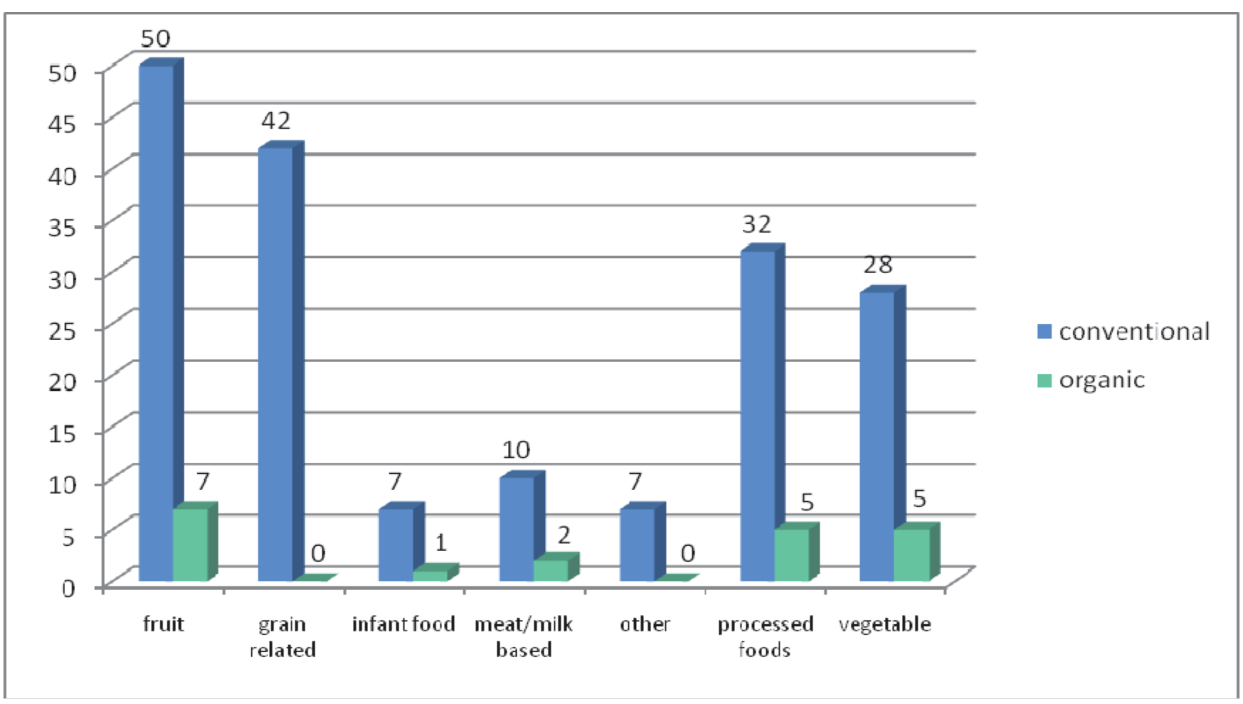


Fig. 8. Frequency of positive conventional and organic samples in foods tested by the British Pesticide Residues Committee 2001-2003 (Benbrook, 2004)

Department of Primary Industries, Victoria, Australia, supervised the monitoring of the quality of organic food in 2002-2003. The study was based on 300 samples of food, of which two-thirds were vegetables and herbs, one-third – fruit, and only 4% of the samples were cereals and oilseeds. The analytical methods allowed detecting such pesticides as organophosphate, organochloranes, triazine herbicides, carbamate insecticides, synthetic pyrethroids and a fungicide, iprodione.

Of the 300 samples tested, only two contained residues of chemical pesticides. In one of cantaloupes there was found dieldrin, banned organochlorine compound. In one of apples, however, there was present post-harvest fungicide, iprodione in trace amounts. Subsequent investigation at apple supplier's cleared this case, because the apples were stored in wooden boxes, which had previously contained fungicide treated fruit (Benbrook, 2004).

In Poland there were also conducted studies of pesticide residues in organic food. As in Sweden, samples from all three farming systems were subjected to analysis. The first such study, conducted in 2004, brought very surprising results, because among the organic raw materials there was not found any sample contaminated with pesticides. The largest percentage of raw materials containing such residues was found in integrated production (50%), leaving in this respect conventional production behind (44%). Theoretically, integrated agriculture is based on the rational use of chemical plant protection products, but so far there is no legal framework governing this sector of agriculture. Therefore, this result is possible, though it seems amazing (Gnusowski *et al*., 2005). This phenomenon can be explained by the specificity of the Polish agriculture, so-called conventional farming. Polish farmers are very diverse in terms of quantities of pesticides used: many farms use only minimal quantities or do not use them at all – this is so-called extensive farming. In contrast, some farmers belonging to minorities use large amounts of pesticides if they produce for a large city market, such as Warsaw, Krakow and Poznan. This particularly concerns the production of vegetables and fruit. If the level of pesticides in both types of households is averaged, generally the level used on conventional farms will be quite low. In Poland, an integrated method is mainly used by fruit-growers who regularly use pesticides, unlike the extensive farmers. It causes a paradoxical result of higher content of pesticides in integrated raw materials compared to conventional ones.

The results of studies conducted in 2005 and 2006 were similar, confirming the highest raw material contamination with pesticides in integrated system (Gnusowski *et al.,* 2006; 2007). Different levels of contamination in the Polish agricultural products grown by different methods are shown in Figure 9. Attention is paid to a downward tendency of conventional raw material contamination, which is not observed in the integrated production.

According to the research of the years 2004-2007, carried out in Poland by Szpyrka *et al.* (2008), the share of contaminated organic raw materials amounts to 3.6%. Later studies of 2007 (Gnusowski *et al.,* 2008) confirmed the presence of pesticide residues in 14.4% of organic samples, while in accordance with the results of recent studies (Gnusowski *et al.,* 2009), in 2008 the figure was 4.4%.

In Baden-Württemberg (Organic Monitoring, 2002-2009), for several years there was conducted monitoring of the quality of organic food available in the German market. One of the parameters were pesticide residues in fruit and vegetables. Among the conventional raw materials, 88% were contaminated with pesticide residues, and the average number of detected active substances was 3.9 per sample. In the case of organic products, pesticide residues were found in 27% of samples (typically, however, there were trace amounts, slightly above the limit of quantification). On average, 0.5 of active substances fell to one sample of organic group. The actual results of research conducted on fruit and vegetables are presented in Figure 10.

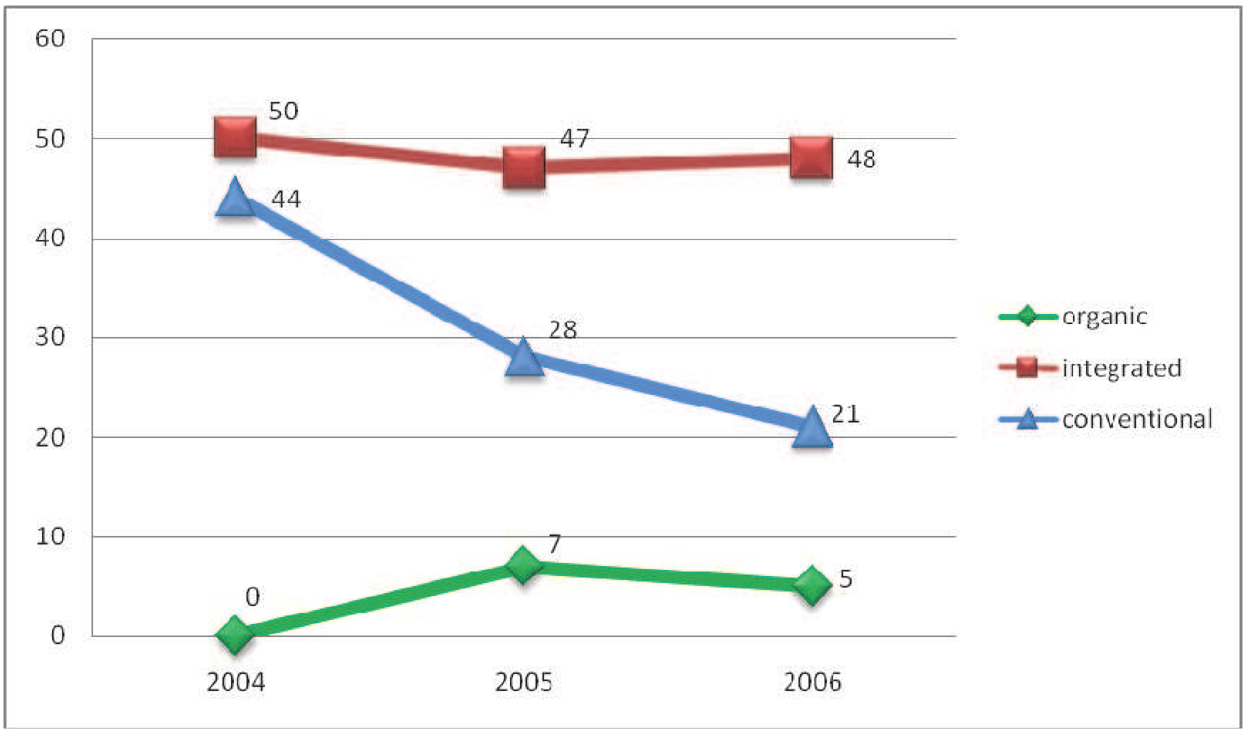


Fig. 9. The pesticide residues found in organic, integrated and conventional food in Poland (%) (Gnusowski *et al.*, 2005; 2006; 2007)

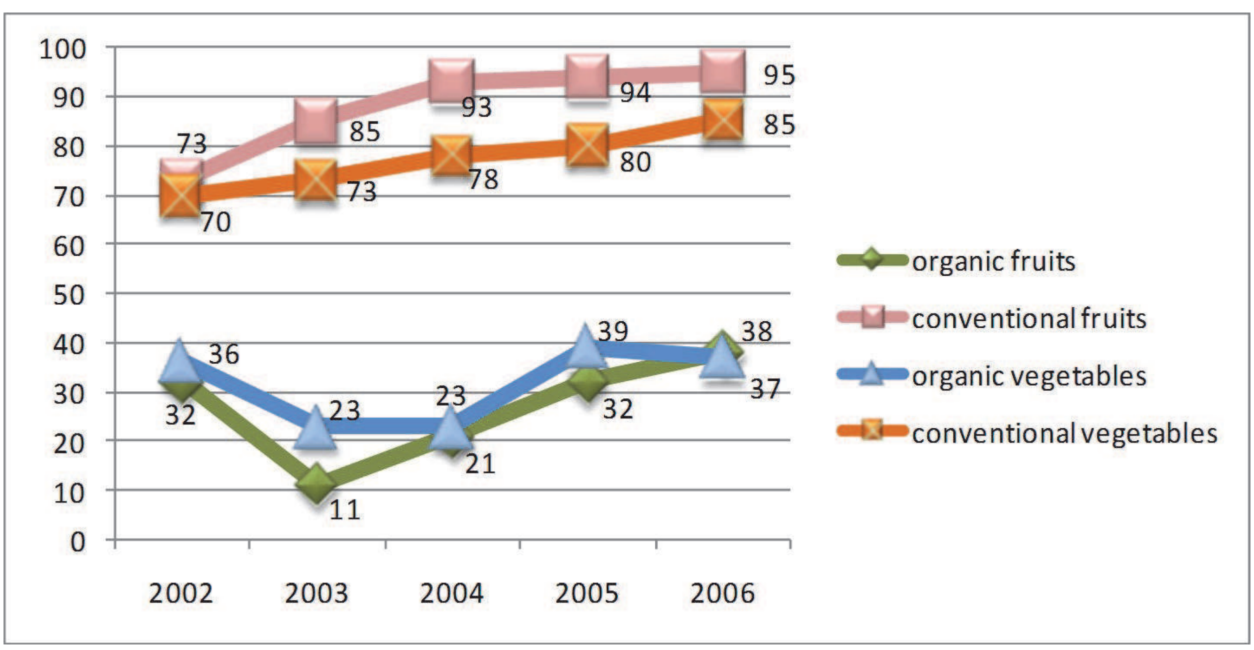


Fig. 10. The residue situation in fruits – organic vs. conventional (%) (Organic Monitoring, 2002-2006)

Figure 11 illustrates the percentage of specific pesticide contaminated raw materials, examined under monitoring in Germany. It makes one think that this percentage is very high among the conventional products. Germany is in fact a society of fairly developed ecological awareness. Relatively many contaminated samples were also found in the case of organic cultivated mushrooms and sweet peppers, which is troubling and requires further research.

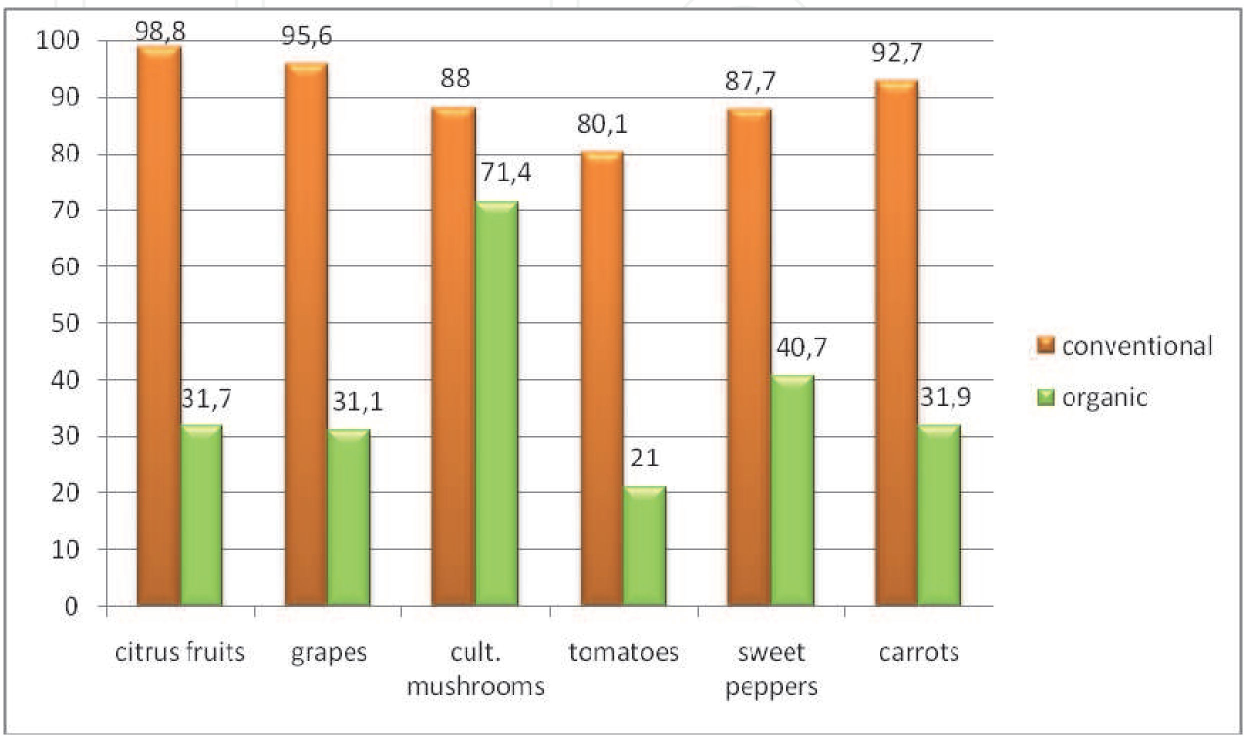


Fig. 11. The percentage of the samples of the food groups with residues – comparison between conventional and organic [%] (Organic Monitoring, 2002-2006)

The latest results of the studies in this field come from Germany (of 2009) (Organic Monitoring, 2010). The tendency towards less frequent occurrence of pesticide residues in organic raw materials remained unchanged, like the high percentage of contaminated samples of cultivated mushrooms. Detailed data are shown in Figure 12.

The above studies also brought interesting results in terms of average pesticide levels in raw materials from different production systems. It turns out that the residues of plant protection chemicals in organic products are not only much less frequent, but also in much smaller concentrations. The average levels of these contaminants in vegetables and fruit over the years 2005 – 2009, found in Germany, are presented in Figure 13.

Apart from the above research, control studies of organic raw materials tested for pesticide residues were also carried out in various other countries. The overall results of the studies are presented in Table 1.

The level of pesticide residues in plants is dependent on the species as well as the active substance of a given product. The substances used have varying toxicity, are characterized by different MRL values, and therefore, the comparison of their contents in the analyzed raw materials does not give the right conclusions. Thus, it is justified to carry out a comparative analysis of pesticide content in products where their presence has been detected. On this basis, one can assess the health risk of consumers exposed to a greater or lower amount of toxic chemical compound. Such studies were conducted by Baker *et al.* (2002). According to their results, the greatest differences are seen between the content of

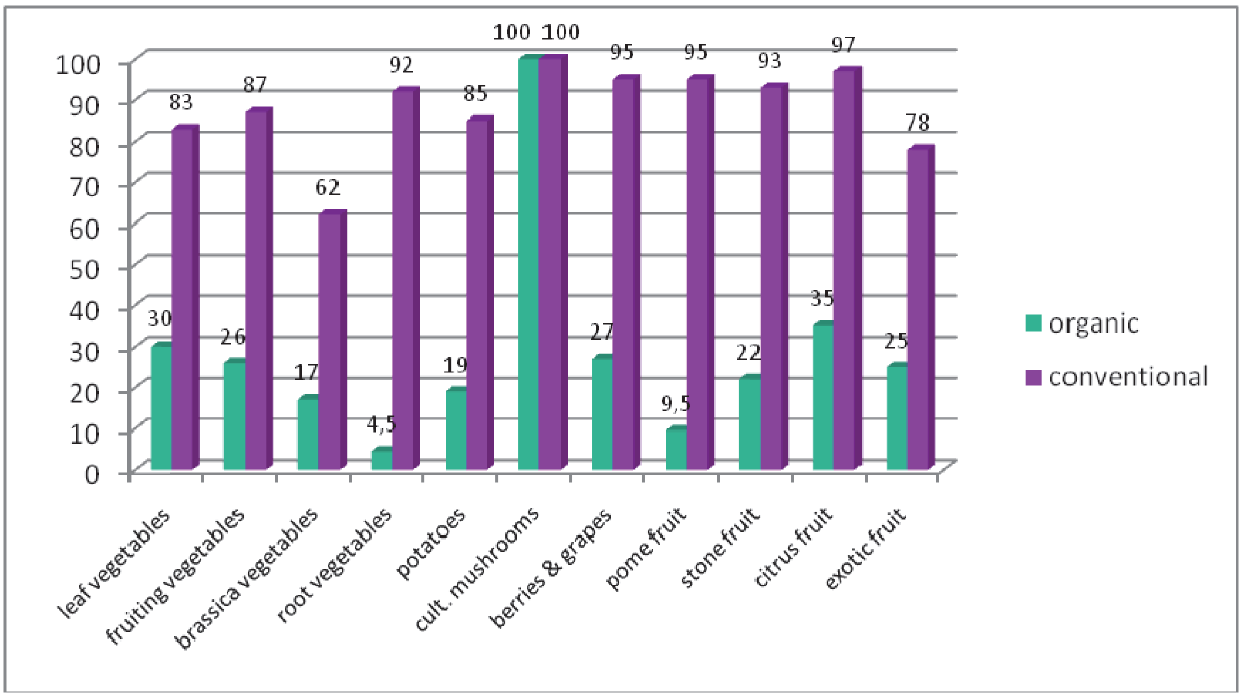


Fig. 12. The percentage of the samples of the food groups with residues – comparison between conventional and organic [%] (Organic Monitoring, 2010)

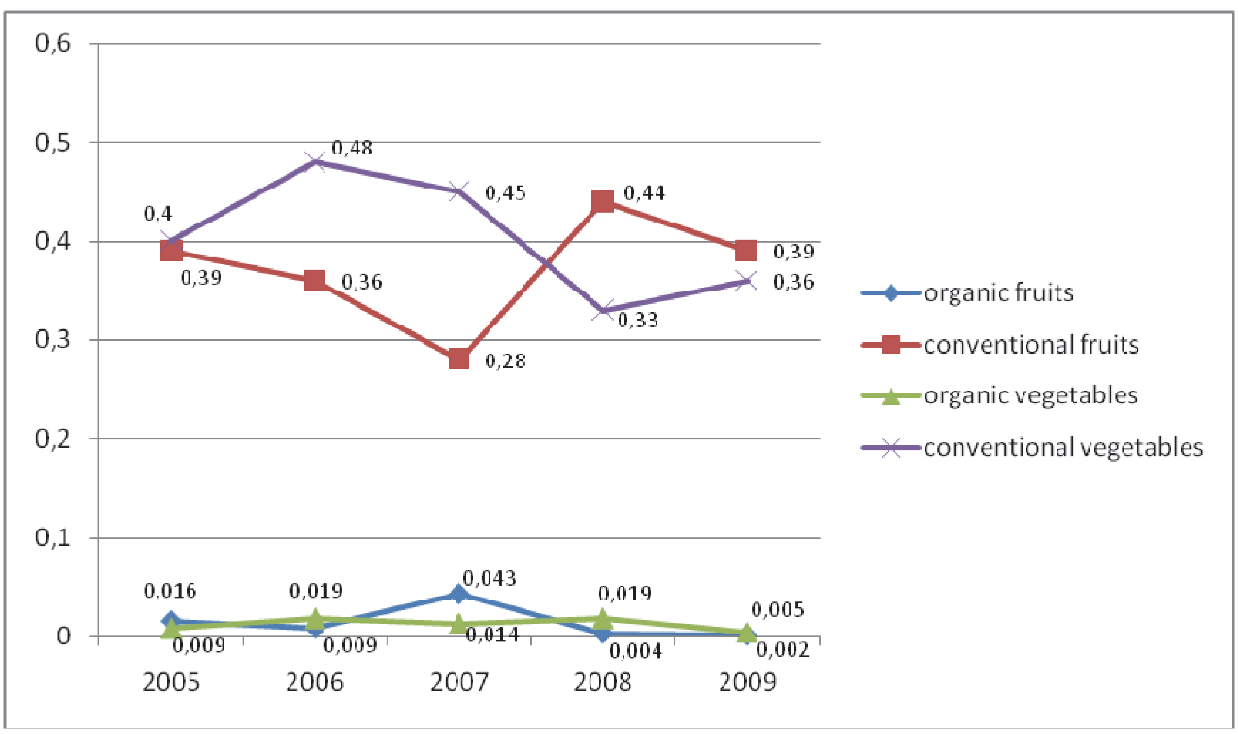


Fig. 13. The average levels of pesticide residues in conventional and organic raw materials in Germany (Organic Monitoring, 2005; 2006; 2007; 2008; 2009)

country	% of samples containing residues
The Czech Republic 2005 (Report, 2006)	14
Ireland 2004-2006 (Pesticides, 2006; 2006a; 2008)	11
Finland 2005-2007 (Pesticide, 2007; 2007a; 2008)	5
Denmark 2002-2003 (Andersen *et al.*, 2004)	3
New Zealand 2004 (Comparison, 2004)	22

Table 1. The comparison of organic crop contamination with pesticide residues

ortho-phenylphenol (commonly used fungicide) in organic and conventional pears. In case of the first ones, the level of the tested compound was more than 22-fold lower. Equally impressive results were obtained in the case of strawberries - the average level of iprodione (also a fungicide) in conventional strawberries turned out to be 7-fold higher than in organic ones. But you cannot ignore the fact that in few raw materials proportions were reversed, as was the case with pepper, celery, grapes and spinach. Ultimately, however, summing up all tested fruit and vegetables from both production systems, the average level of plant production chemicals was approximately 1.7 times higher in the conventional market raw materials (Baker *et al.*, 2002).

The same calculations were made by Benbrook (2004), who compared the contents of selected compounds that had been detected both in conventional and organic raw materials. The greatest value of the ratio of the average pesticide content in a conventional vegetable to the average level of an organic vegetable was 79.55 and concerned chlorthalonil concentration in celery. However, the average value of this ratio for the examined pesticides in the analyzed raw materials was 9.51 (Benbrook, 2004).

4. Pesticide residues in food and their contents in the human body

Undesirable effect of pesticide use in agriculture is not only the contamination of raw materials being grown, but also their movements along the food chain. The man is on its end and this is his health and life which should be a priority in risk assessment and determination of food safety. For this purpose, there are carried out studies to help answer the question of the extent to which chemicals are absorbed along with food, what their distribution in the body is and what affects their quantity.

One of the first studies concerning the relationship between the level of pesticide residues in the diet and their amount in the human body was carried by Aubert in 1987. The subject of analysis was the content of chlorinated hydrocarbons in woman's milk. Persons from whom milk samples were taken consumed organic products, but to varying degrees - their share in the diet was diverse. It was proved that organic food consumption adversely affects the content of chlorinated hydrocarbons in the milk of a tested woman. The largest quantities of pesticides were detected in people who had consumed organic products most rarely (Aubert, 1987). The observed tendency is shown in Figure 14.

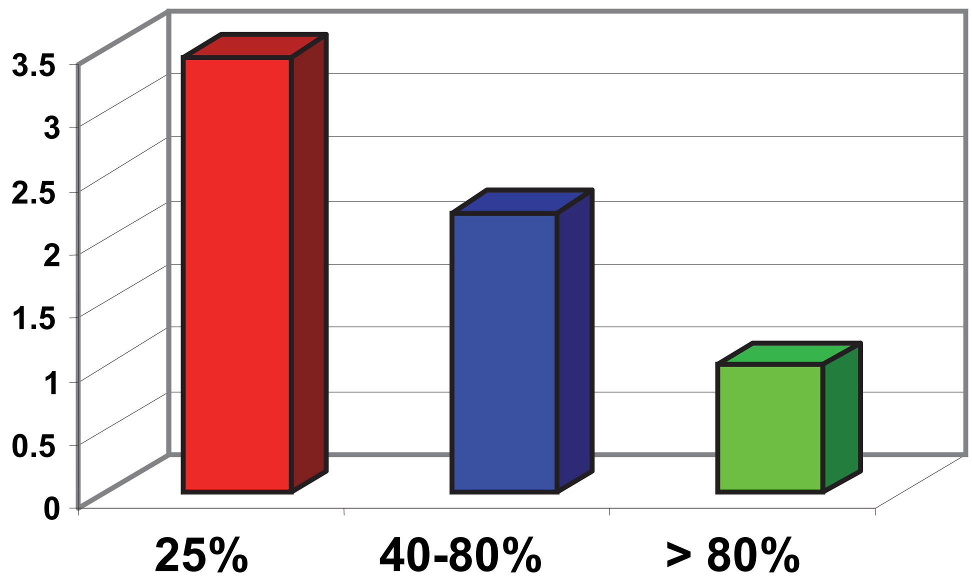


Fig. 14. Total content of chlorinated hydrocarbons in human milk (mg/kg milk fat) (Aubert, 1987)

Curl *et al.* (2003) conducted a study in the United States on children in preschool age. The degree of exposure to pesticide residue poisoning was intended to reflect the level of organophosphate insecticide metabolites, detected in the urine. The study included two groups of children - the first of them, numbering 18 persons, for three days prior to the collection of material for analysis had consumed only certified organic products. Nutrition of the second group of children was based on conventional market products. According to the results of the analyses, in the urine of organically fed children there were found smaller quantities of dimethyl metabolites - dimethylphosphate (DMP), dimethylthiophosphate (DMTP) and dimethyldithiophosphate (DMDTP) - see Figure 15. Total concentration of these metabolites was more than 8-fold lower in children on organic diet rather than children from another study group. In the case of diethyl metabolites – diethylphosphate (DEP) and diethylthiophosphate (DETP) - there were no significant differences. Moreover, the presence of DMP, DMTP, and DMDTP in urine was found significantly more often in conventionally fed children. The percentage of positive results of the analyses on organic diet children turned out to be significantly lower in case of these compounds (Curl *et al.*, 2003).

The 'cross over' type study was conducted on children of school age by Lu *et al.* (2006). The experiment consisted of three consecutive stages. The first phase lasted three days, during which children consumed conventional food. During the second stage, lasting five days, the diet was based on organic products. The third part of the study lasted seven days and returned to a conventional diet. The subject of analysis was the urine of participants and the content of organophosphate insecticide metabolites. It was observed that at the time of transition to organic food the content of MDA (malathion dicarboxylic acid, a metabolite of malathion) and TCPY (3,5,6-trichloro-2-pyridinol, a metabolite of chlorpyrifos) fell below the limit of detection and did not increase until the return of participants to a conventional diet. These active substances are ingredients of pesticides most commonly used in modern

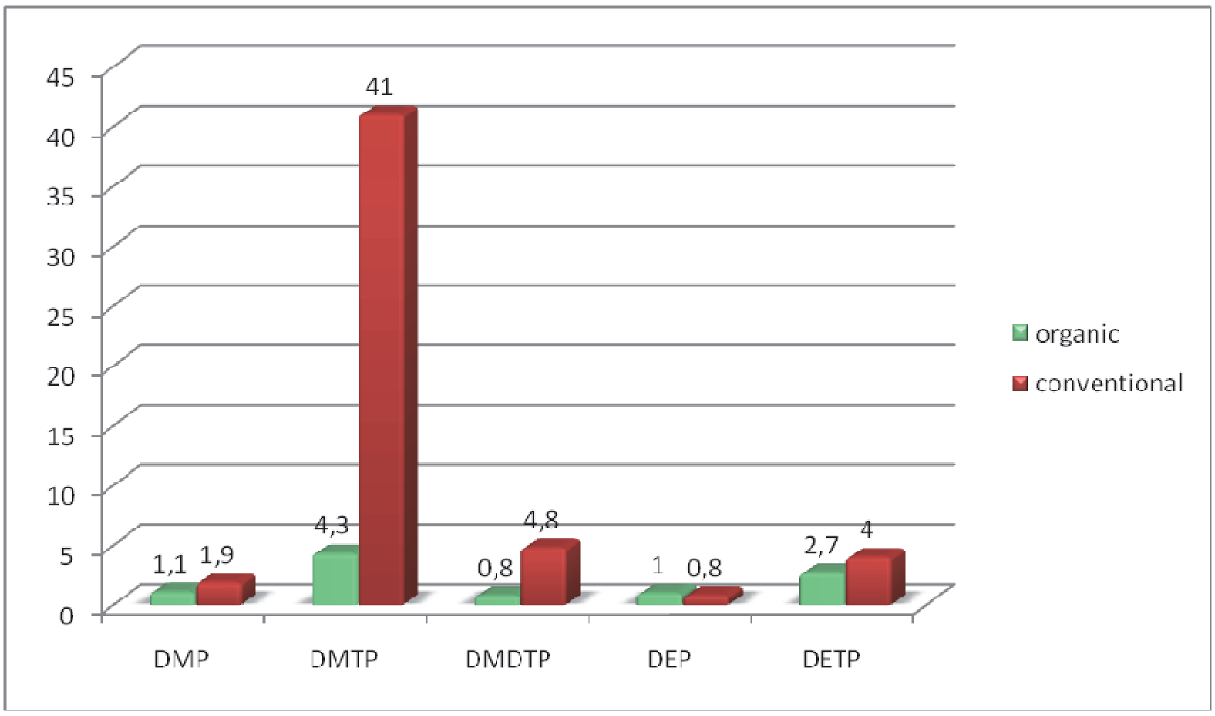


Fig. 15. Individual dialkylphosphate metabolites concentrations (μg/L) in the urine of children on organic and conventional diets (Curl *et al.*, 2003)

agriculture. As for the other metabolites of organophosphate insecticides, their concentrations were also lower during the organic diet phase, but due to the low detection rate, these results could not be considered statistically significant (Lu *et al.*, 2006). Mean levels of MDA and TCPY in subsequent stages of the study are presented in Figure 16.

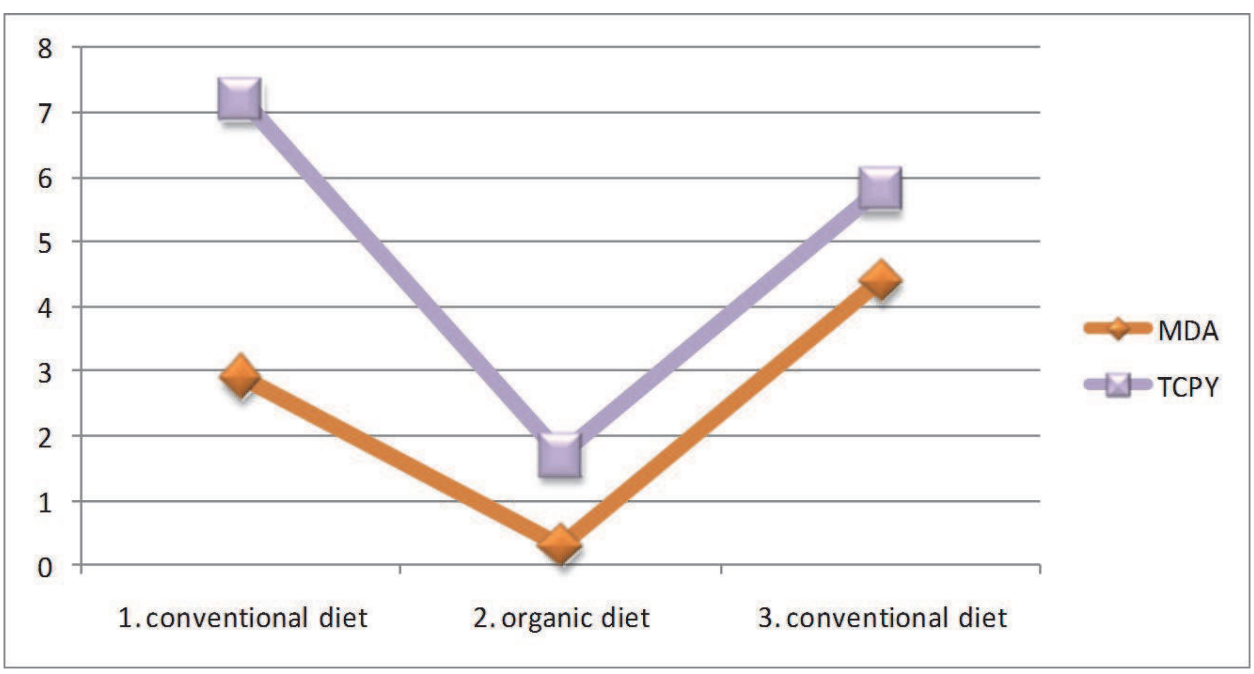


Fig. 16. Mean levels of MDA and TCPY in subsequent stages of the study (μg/L) (Lu *et al.*, 2006)

It must be added that the detection rate of the above-mentioned metabolites in urine also dropped dramatically during the second phase of the study. The percentage of samples containing MDA decreased from 60% to 22%, then back along with a conventional diet increased to the same value of 60%. For TCPY, there was a fall from 78% to 50% at the onset of the second stage, and with its completion the detection rate was 78% again.

5. Discussion

Certified organic products are created without the use of chemical plant protection products, so there is a question about the source of these few cases of pesticide contamination of such raw materials.

The answer to this question is complex. First, the pesticides are widely used around the world, having a mobile nature in agroecosystems. Organic farms do not constitute places of isolation, and are often adjacent to fields where pesticides are used. These products are often spread in the air and reach the places where plants are grown organically. Sprays applied by aircraft hit the target crop at about 25%, while the remainder of the pollutant load is dispersed to other places. When a pesticide is applied using ground-based machines, even at light wind losses amount to approx. 25% of the substance (Benbrook, 2004).

Another factor favouring the migration of chemicals is field watering, through which contaminants can be transferred along the drainage canals. Flowing water is polluted on one of conventional farms, and can get to organic farming. The growing plants absorb chemicals and that is how the contamination of organic crops happens. A similar transfer can take place by the means of dust suspended over the field as well as fog.

Some chemicals, such as organochlorine pesticides, accumulate in the soil. The products, such as chlordane, DDT, toxaphene, dieldrin, and their derivatives, are characterized by very high persistence in the soil environment - despite the fact that they have not been used for 20 years or longer, their residues can still be detected in soil profiles. In addition, some plants, such as cucumbers, melons, carrots, spinach and potatoes, have a great ability to absorb the soil-bound organochlorine compound residues. For this reason, there are cases when certification bodies or companies producing baby food require adequate testing on soils in terms of their contamination with organochlorine compounds (Benbrook, 2004).

The above-mentioned substances also often come to animal fodder and fodder concentrates, so their residues can then be detected in meat, eggs and dairy products.

So-called human factor is no less important in the quality of organic crops in terms of the presence of pesticides, which is the deliberate use of prohibited chemicals. Such practices are illegal and if proved, result in the loss of certificate. The control system is not perfect and sometimes fails to detect farmer's dishonesty.

It is consoling, however, that - as the studies adduced in this chapter prove - even if pesticide residues are found in organic raw materials, usually their content is much lower compared to conventional market products.

6. Conclusions

A number of comparative studies conducted in different countries mostly confirms that in the case of organic products there is 3-4-fold lower likelihood of the presence of pesticide residues than in conventional market products. The chance that organic raw material will include several pesticides at the same time can be up to 11-fold lower than for conventional one. Numerous analyses have shown that the average level of organic product contamination with pesticides is 3-fold or even 10-fold lower than the average concentration of the same compound in conventional products.

Consequently, human exposure to poisoning by pesticide residues is much lower with consumption of organic fruit and vegetables.

On the conventional food market there is a group of raw materials, which is generally characterized by high contamination with pesticides, and this is often consumed by infants and children. This group includes fruit like strawberries, apples, cherries, peaches, pears and nectarines, and vegetables such as spinach, celery and sweet bell peppers. These raw materials are commonly contaminated even with several pesticides and it rarely happens that they are totally free of such residues. For this reason, consumption of these raw materials from organic sources is particularly desirable, especially for pregnant women, infants and children.

Lower exposure means lower risk of poisoning and complications associated with the accumulation of harmful compounds in the body. The spectrum of health problems that are caused by active substances contained in plant protection products is very broad: they damage the nervous system, weaken the immune system, promote the development of tumours and have mutagenic effects. Organic food, despite complete control of the production process and the prohibition of the use of pesticides, will never be 100 percent free of residues of such substances. They have already been used for decades, and conventional farming, which still dominates the world's agricultural landscape, nevertheless affects much less numerous organic crops. However, given the scale of the harmful impact of pesticides on human health, any attempt to eliminate or reduce exposure to their effects should be undertaken and supported. In this respect, organic farming is a very effective way to reduce the risks from chemicals use in agricultural production, and thus it may indirectly contribute to improving our health condition.

7. References

Abdel Rasoul, G.M., Abou Salem, M.E., Mechael, A.A., Hendy, O.M., Rohlman, D.S. & Ismail, A.A. (2008). Effects of occupational pesticide exposure on children applying pesticides. *Neurotoxicology* 29 (5), 833-8.

AFSCA-FAVV (2001). Chemical safety of organically produced foodstuffs. Report from the scientific committee of the Belgian federal agency for the safety of the food chain (AFSCA-FAVV), Brussels.

Andersen, J.H., Erecius Poulsen, M., Liljeroth Lindeberg Bill, R. (2004). Results from the monitoring of pesticide residues in fruit and vegetables on the Danish market 2002-2003. 5th European Pesticide Residues Workshop „Pesticides in Food And Drink", 157, Stockholm, Sweden.

AnsarAhmed, S. (2000). The immune system as a potential target for environmental estrogens (endocrine disrupters): a new emerging field. *Toxicology* 156, 191–206.

Aubert, C. (1987). Pollution du lait maternel, une enquete de Terre vivante. *Les Quatre Saisons du Jardinage* 42, 33-39.

Baker, B.P., Benbrook, C.M., Groth, E. & Benbrook, K.L. (2002). Pesticide residues in conventional, integrated pest management (IPM)-grown and organic foods: insights from three US data sets. *Food Additives and Contaminants* 19, 427-446.

Benbrook, C.M. (2004). Minimizing pesticide dietary exposure through the consumption of organic food, The Organic Center for Education and Promotion. http://www.organic-center.org

Commission Regulation (EC) No 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labeling and control (OJ L 250, 18.9.2008, p. 1).

Comparison of Residues In Conventional And Organic Produce In New Zealand (2004). New Zealand Food Safety Authority, New Zealand. www.nzfsa.govt.nz/consumers/food-safety-topics/chemicals-infood/residues-in-food/consumer-research/org-conv-comp.pdf

Curl, C.L., Fenske, R.A. & Elgethun, K. (2000). Organophosphorus Pesticide Exposure of Urban and Suburban Preschool Children with Organic and Conventional Diets. *Environ Health Perspect* 111, 377–382.

Eddleston, M., Buckley, N.A., Eyer, P. & Dawson, A.H. (2008). Management of acute organophosphorus pesticide poisoning. Lancet, February 16; 371 (9612), 597–607.

EFSA Journal (2010). Scientific Report of EFSA, 2008 Annual Report on Pesticide Residues according to Article 32 of Regulation (EC) No 396/20051, European Food Safety Authority. European Food Safety Authority (EFSA), Parma, Italy, 8(6): 1646.

EFSA Scientific Report (2009). 2007 Annual Report on Pesticide Residues according to Article 32 of Regulation (EC) No 396/20051. Prepared by Pesticides Unit (PRAPeR) of EFSA (Question No EFSA-Q-2008-714), 305, 1-106.

Gilman, A.P., Van Oostdam, J.C., Hansen, J.C., Odland, J.O., Tchachtchine, V., Walker, J., Lagerkvist, B.J., Olafsdottir, K., Weber, J.P., Bjerregaard, P. & Klopov, V. (1997). The AMAP International Symposium on Environmental Pollution in the Arctic. (Extended Abstracts volume1: 57-58). Tromso, Norway, June 1-5.

Gnusowski, B. & Nowacka, A. (2007). Pozostałości środków ochrony roślin w polskich płodach rolnych pochodzących z różnych systemów gospodarowania. *Fragmenta Agronomica* 3 (95), 121-125.

Gnusowski, B., Nowacka, A. & Sadło, S. (2008). Pozostałości środków chemicznej ochrony roślin w płodach rolnych, roślinnych produktach spożywczych i paszach pochodzących z produkcji ekologicznej w roku 2007. *Progress in Plant Protection* 48 (4), 1194-1198.

Gnusowski, B., Nowacka, A., Walorczyk, S., Łozowicka, B., Szpyrka, E. & Sadło, S. (2009). Badania pozostałości środków chemicznej ochrony roślin w płodach rolnych, roślinnych produktach spożywczych i paszach pochodzących z produkcji ekologicznej w roku 2008. *Progress in Plant Protection* 49 (4), 1857-1863.

Gnusowski, B., Szymona, J. & Sadło, S. (2006). Pozostałości środków chemicznej ochrony roślin w żywności pochodzenia roślinnego produkowanej metodami ekologicznymi w Polsce w roku 2005. *Progress in Plant Protection* 46 (1), 495-501.

Gnusowski, B., Szymona, J. & Sadło, S. (2007). Pozostałości środków chemicznej ochrony roślin w żywności i paszach pochodzenia roślinnego produkowanej metodami ekologicznymi w Polsce w roku 2006. *Progress in Plant Protection* 47 (4), 42-48.

Gnusowski, B., Szymona, J. & Sadło, S. (2005). Pozostałości środków chemicznej ochrony roślin w żywności pochodzenia roślinnego produkowanej metodami ekologicznymi w Polsce w roku 2004. *Progress in Plant Protection* 45 (1), 146-151.

Guillette, E.A., Meza, M.M., Aquilar, M.G., Soto, A.D. & Garcia, I.E. (1998). An Anthropological Approach to the Evaluation of Preschool Children Exposed to Pesticides in Mexico. *Environmental Health Perspectives* – Volume 106, Number 6, 347-353.

Howard, V. (2005). Pesticides and Health. [in:] A lecture at the Congress: "Organic Farming, Food Quality and Human Health". 5–6 January 2005, Newcastle, UK.

Irmler, U. (2003). The spatial and temporal pattern of carabid beetles on arable fields in northern Germany (Schleswig-Holstein) and their value as ecological indicators. *Agriculture Ecosystems & Environment* 98, 141-151.

Jończyk, k. (2005). Płodozmiany w gospodarstwie ekologicznym. Centrum Doradztwa Rolniczego w Brwinowie Oddział w Radomiu, ISBN 83-60185-06-9.

Kromp, B. (1989). Carabid beetle communities (Carabidae, Coleoptera) in biologically and conventionally farmed agroecosystems. *Agriculture Ecosystems & Environment* 27, 241-251.

Lu, C., Toepel, K., Irish, R., Fenske, R.A., Barr, D.B. & Bravo, R. (2006). Organic Diets Significantly Lower Children's Dietary Exposure to Organophosphorus Pesticides. Environ Health Perspect 114: 260–263.

Nowak, C. (2004). GMO – różnica stanowisk USA i UE. Konferencja Czy chcemy żyć z GMO? *Aspekty gospodarcze, ekologiczne i etyczne stosowania produktów GMO*, 1-3.

Odum, J., Lefevre, P.A., Tittensor, S., Paton, D., Routledge, E.J., Beresford, N.A., Sumpter, J.P. & Ashby, J. (1997). The rodent uterotrophic assay: critical protocol features, studies with nonyl phenols, and comparison with a yeast estrogenicity assay. *Reg Toxicol Pharmacol* 25, 176-188.

Organic Monitoring summary report (2002-2006). Programm der Lebensmittelüberwachung, Chemische und Veterinäruntersuchungsämter Baden-Württemberg, CVUA Stuttgart, Germany, 1-16.

Organic Monitoring summary report (2007). Chemische und Veterinäruntersuchungsämter Baden-Württemberg, CVUA Stuttgart, Germany, 1-67.

Organic Monitoring summary report (2008). Chemische und Veterinäruntersuchungsämter Baden-Württemberg, CVUA Stuttgart, Germany, 1-78.

Organic Monitoring summary report (2009). Programm der Lebensmittelüberwachung, Chemische und Veterinäruntersuchungsämter Baden-Württemberg, CVUA Stuttgart, Germany, 1-68.

Pennycook, F.R., Diamand, E.M., Watterson, A. & Howard, W. (2004). Modeling the dietary pesticide exposures of young children. *International Journal of Occupational and Environmental Health* 10 (3), 304-309.

Pesticide residue monitoring in Finland – 2005 (2007). Evira publication 5/2007. http://www.evira.fi

Pesticide residue monitoring in Finland – 2006 (2007a). Evira publication 20/2007. http://www.evira.fi

Pesticide residue monitoring in Finland – 2007 (2008). Evira publication 11/2008. http://www.evira.fi

Pesticides residues in food 2004 (2006). The Stationary Office, Dublin, Ireland. http://www.pcs.agriculture.gov.ie

Pesticides residues in food 2005 (2006a). The Stationary Office, Dublin, Ireland. http://www.pcs.agriculture.gov.ie

Pesticides residues in food 2006 (2008). The Stationary Office, Dublin, Ireland. http://www.pcs.agriculture.gov.ie

Report of Pesticide Residue Monitoring Results of the Czech Republic for 2005 (2006). http://www.szpi.gov.cz/en/docDetail.aspx?docid=1004282&docType=ART&nid=11452

Richter, E.D. (2002). Acute Human Pesticide Poisonings. Encyclopedia of Pest Management, Taylor & Francis, 3-6.

Szpyrka, E., Machowska, A. and Sadło, S. (2008). Residues of plant protection products in organic food of plant origin in South-Eastern Poland in 2004-2007. *Journal of Research and Applications in Agricultural Engineering,* Vol. 53 (4), 101-103.

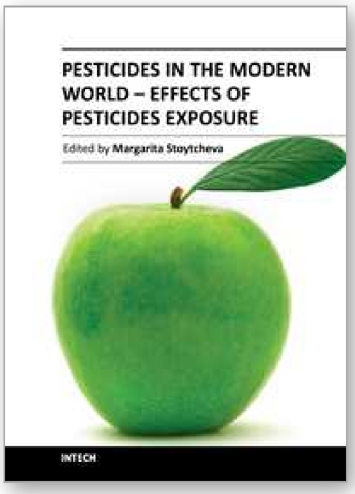
The Swedish Monitoring of Pesticide Residues in Food of Plant Origin (2003). Livsmedelsverkets rapport nr 12/2003.

The Swedish Monitoring of Pesticide Residues in Food of Plant Origin (2004). EC and National Report, Livsmedelsverkets rapport nr 12/2004.

The Swedish Monitoring of Pesticide Residues in Food of Plant Origin (2005). EC and National Report, Livsmedelsverkets rapport nr 17/2005.

WHO (2010). World Health Statistics 2010. WHO Statistical Information System. http://www.who.int/whosis/whostat/EN_WHS10_Full.pdf

WHO Technical Report Series No. 513 (1973). Safe use of pesticide: twentieth report of the WHO Expert Committee on Insecticides.



Pesticides in the Modern World - Effects of Pesticides Exposure
Edited by Dr. Margarita Stoytcheva

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The introduction of the synthetic organochlorine, organophosphate, carbamate and pyrethroid pesticides by 1950â€™s marked the beginning of the modern pesticides era and a new stage in the agriculture development. Evolved from the chemicals designed originally as warfare agents, the synthetic pesticides demonstrated a high effectiveness in preventing, destroying or controlling any pest. Therefore, their application in the agriculture practices made it possible enhancing crops and livestockâ€™s yields and obtaining higher-quality products, to satisfy the food demand of the continuously rising worldâ€™s population. Nevertheless, the increase of the pesticide use estimated to 2.5 million tons annually worldwide since 1950., created a number of public and environment concerns. This book, organized in two sections, addresses the various aspects of the pesticides exposure and the related health effects. It offers a large amount of practical information to the professionals interested in pesticides issues.