Appendix no. 2

Ph. D. Ewelina Wiktoria Hallmann

The comparison of nutritive value as well as the content of bioactive compounds in selected Solanaceae vegetables from organic and conventional production with some processing elements

Habilitation thesis

Warsaw University of Life Sciences

Faculty of Human Nutrition and Consumer Sciences

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I. Scientific activity

1. Personal data

Ewelina Wiktoria Hallmann

2. Diploma and scientific degrees – with name, place and year of obtained

2003 – Doctor of the agriculture sciences, area: horticulture, specialty: vegetables, Warsaw University of Life Sciences, the title of thesis: The estimation of yield and fruits quality of selected tomato types cultivated on mineral rockwool, Supervisor: prof. dr hab. Jolanta Kobryń, Reviewers: prof. dr hab. Henryk Skąpski, prof. dr hab. Andrzej Libik;

1999 – Master Sciences, major: horticulture, specialty: vegetable plants, Warsaw University of Life Sciences, the title of thesis: The estimation of glutathione and ascorbinian level as antioxidant's system elements in selected cruciferous vegetables genotypes, Supervisor: dr hab. Barbara Łata, Reviewer: prof. dr hab. Monika Rakoczy-Trojanowska

3. The information about employment in scientific organizations

1999 – 2003	**Doctor study** on Horticulture and Landscape Faculty, Warsaw University of Life Sciences;
2005 – present	**Adjunct** in Department of Functional, Organic Food and Commodities, Faculty of Human Nutrition and Consumer Sciences, Warsaw University of Life Sciences, Warsaw;

4. The establishment of scientific achievement as background of habilitation thesis

Osiągnięciem naukowym wynikającym z art. 16 ust. 2 ustawy z dnia 14 marca 2003 roku o stopniach naukowych i tytule naukowym oraz o stopniach i tytule w zakresie sztuki (Dz. U. Nr 65, poz. 595 ze zm.) jest jednotematyczny cykl publikacji naukowych, który habilitantka zatytułowała: „**The comparison of nutritive value as well as the content of bioactive**

compounds in selected Solanaceae vegetables from organic and conventional production with some processing elements ".

The publications include to habilitation thesis:

[H1]. Rembiałkowska E, **Hallmann E.,** Wasiak-Zys G. 2003. The nutritive and sensory value of tomatoes from organic and convenytional production, Żywienie Człowieka i Metabolizm, Suplement, t. 30, z. 3/4, s. 893-899**.** (IF 0[1]; MNiSW 1; cytowany 0)

Individual contribution*: corresponding author, evaluation of analytic methods, analysis of plant material, statistically elaboration of obtained results, experiment description, graphical presentation of results, manuscript preparing (40%)*

[H2]. **Hallmann E.** 2012[1]. The influence of organic and conventional cultivation systems on the nutritional value and content of bioactive compounds in selected tomato types, Journal of the Science of Food and Agriculture, v. 92, i. 14, p. 2840-2848 (IF 1,36; MSHE 35; referred 2)

Individual contribution*: corresponding author, evaluation of analytic methods, analysis of plant material, statistically elaboration of obtained results, experiment description, graphical presentation of results, wording of conclusions, manuscript preparing (100%)*

[H3]. **Hallmann E**., Rembiałkowska E. 2008[1]. The estimation of nutritive and sensory value of tomato and tomatoes juice from organic and conventional production, Journal of Research and Applications in Agricultural Engineering, v. 53, i.3, p. 88-95 (IF 0; MSHE 6, referred 2)

Individual contribution*: corresponding author, evaluation of analytic methods, analysis of plant material, statistically elaboration of obtained results, experiment description, graphical presentation of results, manuscript preparing (60%)*

[H4]. **Hallmann E**., Rembiałkowska E., Lipowski J., Marszałek K. 2010[1]. The estimation of nutritive and sensory value of tomato juices from organic and conventional production, Journal of Research and Applications in Agricultural Engineering, v. 55, i.3, p. 105-111 (IF 0; MSHE 6, referred 0)

Individual contribution*: corresponding author, evaluation of analytic methods, analysis of plant material, statistically elaboration of obtained results, experiment description, graphical presentation of results, manuscript preparing (80%)*

[1] Punktację publikacji z lat 2003-2010 obliczono wg listy MNiSW z roku 2010, punktację publikacji z lat 2011-2013 obliczono wg listy MNiSW z roku 2012

[H5]. **Hallmann E.**, Rembiałkowska E., Szafirowska A., Grudzień K. 2007[1]. Significance of organic crops in health prevention illustrated by the example of organic paprika (*Capsicum annuum*), Roczniki PZH, v. 58, i. 1, p. 77-82 (IF 0; MSHE 9, referred 1)

***Individual contribution**: corresponding author, evaluation of analytic methods, analysis of plant material, statistically elaboration of obtained results, experiment description, graphical presentation of results, manuscript preparing (50%)*

[H6]. **Hallmann E**., Rembiałkowska E. 2012[1]. Characterization of antioxidant compounds in sweet bell pepper (*Capsicum annuum* L.) under organic and conventional growing systems, Journal of the Science of Food and Agriculture, v. 92, i. 12, p. 2409-2415 (IF 1,36; MSHE 35; referred 2)

***Individual contribution**: corresponding author, evaluation of analytic methods, analysis of plant material, statistically elaboration of obtained results, experiment description, graphical presentation of results, manuscript preparing (60%)*

[H7]. Rembiałkowska E., **Hallmann E**. 2008[1]. The changing of bioactive compounds in pickled bell pepper fruits from organic and conventional production, Journal of Research and Applications in Agricultural Engineering, v. 53, i.4, p.51-57 (IF 0; MSHE 6; referred 0)

***Individual contribution**: corresponding author, evaluation of analytic methods, analysis of plant material, statistically elaboration of obtained results, experiment description, graphical presentation of results, manuscript preparing (60%)*

[H8]. **Hallmann E.**, Rembiałkowska E. 2009[1]. The influence of pasteurization process and storing on bioactive compound content in pickled red pepper fruits from organic and conventional production, Journal of Research and Applications in Agricultural Engineering, v. 54, i.3, p. 90-95 (IF 0; MSHE 6, referred 0)

***Individual contribution**: corresponding author, evaluation of analytic methods, analysis of plant material, statistically elaboration of obtained results, experiment description, graphical presentation of results, manuscript preparing (70%)*

[H9]. **Hallmann E**., Rembiałkowska E. 2008[1]. The content of selected antioxidant compounds in selected bell pepper varieties from organic and conventional cultivation before and after freezing process. Proceedings of the 2th Scientific Conference of the International Society of Organic Agriculture Research (ISOFAR) (Neuhoff et al. eds.). Modena, 18-20 June, v 2, 802- 805 (IF 0; MSHE 7, referred 0)

***Individual contribution**: corresponding author, evaluation of analytic methods, analysis of plant material, statistically elaboration of obtained results, experiment description, graphical presentation of results, manuscript preparing (60%)*

5. Short review of publications included to habilitation thesis

5.1. Introduction

Tomato (Lycopersicon esculentum Mill.) and bell pepper (Capsicum annuum L.) belong to the nightshade vegetables, and along with potatoes (Solanum tuberosum L.) they represent an important component of vegetable production. Other vegetables from the Solanaceae family, grown in Poland, are eggplant, otherwise known as aubergine (Solanum melongena L.), lesser-known pepino (Solanum muricatum Ait.) as well as cape gooseberry (Physalis peruviana L.). Due to the climatic conditions in Poland, tomato and pepper can be cultivated in two systems: field and under cover (greenhouses, plastic tunnels).

In organic system of tomato and pepper cultivation it is forbidden to use synthetic plant protection products (pesticides) and readily soluble mineral fertilizers (manufactured by chemical synthesis). However, it is allowed to use natural fertilizers (manure, compost, and green manure) to fertilize plants as well as natural plant extracts (grapefruit, garlic or nettle extract), pheromone traps, glue boards and natural enemies to protect the crop. All details concerning plant cultivation in organic system are described in the Council Regulation (EC) No 834/2007 [24]. In Poland, tomato is one of the most important vegetables grown in the field and under cover. It is estimated that in 2012 the conventional field-grown tomatoes were cultivated in the area of 16 thousand. ha, and annual production amounted to 261 thousand. tons. Field production of organic tomatoes accounts for a very small percentage due to the great problems concerning the occurrence of diseases, such as late blight (phytophthorosis) caused by the pathogen Phytophthora infestans [2]. In the case of under-cover production in 2012, the cultivation of conventional tomato in Poland embraced 3.4 thousand. ha, while the yield was equal to 420 thousand. tons. In the case of organic farming it was only 115 ha, with annual production of 15 thousand. tons [23]. The cultivation of pepper in Poland is carried out on a much smaller scale. In 2012, the area of conventional pepper grown under cover amounted to 850 ha, with the yield of 60 thousand. tons. In the case of field pepper it was 80 ha and 10 thousand. tons respectively. There are no data on organic production of peppers grown both under cover or in the open ground [23]. According to the above data, it is clear that for conventional production tomatoes and peppers are an important part of the vegetable production, both for fresh market and processing. In Poland, there is assigned 40-60% of the

annual production of conventional field tomato and 30% of under-cover pepper for processing. Unfortunately, there is no data on organic production of solanaceous vegetables for processing [23]. The organic food market represents an increasingly growing production sector. Due to the seasonality of tomato and pepper crops, a very significant part of maintaining continuity in the consumption of the vegetables is their processing.

Tomato and pepper fruits are a great source of numerous biologically active compounds belonging to the group of carotenoids (carotenes and xanthophylls), polyphenols (phenolic acids and flavonoids), and vitamins (vitamin C) [6], [11], [20], [27]. Due to the antioxidant nature, biologically active compounds can protect the consumer's body against many chronic non-communicable diseases. The group of these diseases includes various cancers (breast, prostate and gastrointestinal tract cancer) and cardiovascular diseases [12]-[13], [17], [19].

The presented collection of publications under the common title "Comparison of nutritional value and the content of biologically active compounds in selected organic and conventional vegetables from the nightshade (Solanaceae) family including processing elements" provides many new cognitive and scientific features regarding the promotion of organic farming of nightshade vegetables in Poland. In 2003-2007, there were carried out first research studies comparing the nutritional value of tomatoes, peppers and their products from organic and conventional farming. The research scope was extended in subsequent publications of the years 2008-2012; they examined and discussed in detail the content of bioactive compounds in Solanaceae vegetables. The studies conducted by the habilitation candidate were innovative in their nature, as in the years 2006-2009, in addition to the Warsaw University of Life Sciences (SGGW), there was only one research centre in Poland conducting similar studies, but on a much smaller scale.

5.2. Research objective and hypotheses

A **main objective** of the thesis presented was an analysis of the impact of cultivation (organic and conventional) on the nutritional value and the content of biologically active compounds of tomatoes and peppers grown in Poland. An **additional aim** was to determine whether there are differences in the content of biologically active compounds in the products made by processing of organic and conventional tomatoes and peppers. A **secondary objective** was to demonstrate how the analytical methods used may contribute to learning and understanding these differences.

In order to achieve the research objectives, the following research hypotheses were put forward:

- Organic methods of plant cultivation determine the yields of high nutritional value, as well as higher levels of bioactive compounds in vegetables and fruits as compared with conventional plants;
- Chemical composition of tomato and pepper is strongly determined by genetic factor, which is the variety, the place of production (e.g. production farm or experimental plots), and the year of cultivation;
- Processing of tomato and pepper fruits contributes to changes in the chemical composition of the final product, which is tomato juice or pickled and frozen pepper;
- The use of advanced analytical techniques can allow a thorough analysis of the compounds belonging to fresh tomatoes and peppers and their products, which may help identify the relationships between various compounds and facilitate a multi-layered interpretation of the problem of quality determination.

5.3. Theoretical grounds of the experimental studies under discussion

In organic farming, the applied organic fertilizers and non-synthetic protection agents have a very strong influence on the chemical composition of fruits and vegetables grown. The variation in the content of biologically active compounds of agricultural crops mainly results from cultivation practices undertaken in organic and conventional systems. In organic farming plants are grown with no use of readily soluble mineral fertilizers, especially nitrogen fertilizers and pesticides. It has been reported that the use of readily assimilable nitrogen contributes to a decrease in the content of secondary metabolites in plant tissues [10]. It has been observed that easy availability of nitrogen - typical of conventional agriculture - causes the change in metabolism of cultivated plants, i.e. the growth processes and reduces the production processes of secondary metabolites. This contributes to a lower content of biologically active compounds in plant tissues. This phenomenon has been identified as the C/N theory [7], [18]. In conventional plants, where easily assimilable nitrogen is available for crops in large quantities, the metabolic processes in the first place include the production of nitrogen-derived secondary metabolites (amino acids, peptides, proteins, and alkaloids). However, in organic plants, where nitrogen is present in the soil only after a number of organic matter mineralization processes, the plant metabolism is orientated in a first stage on

the production of secondary metabolites containing no nitrogen, but carbon-based (simple and complex carbohydrates, carotenoids, polyphenols, and vitamins). Organic farming contributes to the protection of natural environment by imposing a total ban on the use of synthetic agricultural chemicals and promoting natural methods of cultivation. Another positive aspect for the promotion of organic farming is a high biological value of the crop, in particular the content of bioactive compounds in organic fruits and vegetables. For these compounds protect the human body against the free radicals attack and help to promote health, especially in times of increased incidence of chronic non-communicable diseases.

5.4. Results and discussion

Influence of growing conditions on the nutritional value and the content of bioactive compounds in tomato fruits

Publications [H1] and [H2]

Rembiałkowska E, **Hallmann E**., Wasiak-Zys G. 2003. The nutritive and sensory value of tomatoes from organic and convenytional production, Żywienie Człowieka i Metabolizm, Suplement, t. 30, z. 3/4, s. 893-899.

Hallmann E. 2012. **The influence of organic and conventional cultivation systems on the nutritional value and content of bioactive compounds in selected tomato types**, Journal of the Science of Food and Agriculture, v. 92, i. 14, p. 2840-2848

An important aspect of organic vegetables production is the quality of raw materials. Therefore, in the first publication **[H1]** an attempt was made to compare selected items of nutritional value of tomatoes grown in organic and conventional systems. The basis of the comparative experiment was a selection of tomato varieties and their cultivation in compliance with all organic and conventional farming rules. The experiment was carried out in neighbouring farms: a certified organic farm and a typical conventional farm. Both farms were located in similar climatic and soil conditions, so as to minimize the number of factors that may affect the quality of the tomato varieties studied. Another element was the choice of two varieties of standard tomatoes (*Lycopersicon esculentum* Mill), i.e. Atut F_1, and Jontek F_1. In the paper presented, there were examined such parameters as: the content of dry matter, as well as the content of biologically active compounds such as vitamin C, carotenoids (lycopene and beta-carotene), and total flavonoids expressed as quercetin. It is worth noting that in 2003, when the above studies were published, it was one of the first experiments conducted in Poland in the scope of organic tomato cultivation. In the world references published up to now there are only two experiments presenting a similar problem [4]-[5]. In

the publication discussed the care was taken not only to perform chemical analyses, but there were also examined the environmental conditions in which tomatoes were grown. The studies showed that there are differences in the quality of organic and conventional tomatoes. The paper proves that the organic farming method had a significant impact on the content of beta-carotene and flavonoids in the tomato fruits studied. Given the results of the above-mentioned studies, the next stage was commenced, i.e. a deeper analysis of the quality of tomato grown in organic and conventional systems. The result of the action taken is the publication **[H2].** The experiment described in this publication was carried out in a two-year system involving more farms. In addition, the experiment included other tomato varieties: standard tomatoes (Merkury F_1, Akord F_1, and Rumba F_1) and small-berry tomatoes (Conchita F_1 and Picolino F_1). The experiment was conducted in the farms cultivating tomatoes under cover, which assured a precise control of experimental conditions. It is also worth noting that the described methods of analyses based on high performance liquid chromatography, which allowed not only for quantitative analysis of carotenoids and polyphenols, but also a qualitative division of compounds into individual components. In the case of carotenoids it was a very precise separation of lycopene and beta-carotene, and when it comes to polyphenolic compounds there were detected and quantitatively determined two phenolic acids: gallic acid and chlorogenic acid as well as five flavonoid compounds: free quercetin and its derivatives (rutinoside and glycoside), myricetin and kaempferol. All analyses were performed on freeze dried fruit, and not on fresh fruits as in the previous publication. The use of freeze-drying process prevented uncontrolled disintegration of biologically active compounds, especially lycopene, vitamin C and flavonoids in tomato fruits. Another unknown issue in the presented publication was an attempt to demonstrate whether there are any relationships between biologically active compounds determined in tomato fruits and macroelements (nitrogen and potassium) present in the soil during plants cultivation. The regression results helped to discuss the data obtained. In this paper the author has attempted not only to describe the results and compare them to those reported in the world references, but also to interpret and explain plants processes (physiological and environmental ones) determining the synthesis and accumulation of biologically active compounds in tomato fruits. The result of the studies described in the publication **[H2]** was to demonstrate that organic tomatoes contained significantly more quercetin and its derivatives as well as myricetin compared with conventional tomatoes. At the same time it was ascertained that external factors, such as crop year, and internal factors, like type of tomato, had a significant impact on the quality of the fruits. The results clearly illustrate that consumption of organic tomatoes because of their

higher biological value and content of antioxidant compounds may contribute to the health promotion among consumers.

The effect of (organic and conventional) raw material sourcing on the nutritional value and the bioactive compounds content in tomato juice

publications [H3] and [H4]

Hallmann E., Rembiałkowska E. 2008. **The estimation of nutritive and sensory value of tomato and tomatoes juice from organic and conventional production**, Journal of Research and Applications in Agricultural Engineering, v. 53, i.3, p. 88-95

Hallmann E., Rembiałkowska E., Lipowski J., Marszałek K. 2010. **The estimation of nutritive and sensory value of tomato juices from organic and conventional production**, Journal of Research and Applications in Agricultural Engineering, t. 55, z.3, s. 105-111

Tomato is a very valuable raw material for processing. It is also associated with the fact that the fruit is seasonal and only the possibility of processing gives a chance to consume tomatoes throughout the year. Tomato processing products are as follows: juice, puree, sauce, concentrate, ketchup, dried tomatoes (for powdery spice mixes), sun-dried tomatoes marinated in olive oil, peeled tomatoes in juice, and frozen tomatoes [26]. Given such a high demand for these products one should ask themselves what their quality is. The authors of previous papers have shown that organic fruits have a higher biological value in comparison with conventional ones. The processing of tomato changes its physical structure as well as chemical and sensory characteristics. Many technological processes undertaken are based on the use of high (blanching of fruit pulp and pasteurization) or low temperature (freezing). Therefore, a series of articles on tomato processing was to investigate the effect of processing conditions on the final quality of the product obtained, i.e. tomato juice. In the paper **[H3]** there was examined tomato juice produced under controlled laboratory conditions, with specific regard to the tomato varieties studied. The studies included the nutritional value of tomato juice obtained from different production systems and diverse varieties. There were determined such quality parameters as: content of dry matter, sugars, organic acids and glutamic acid. These compounds are determinants of nutritional and sensory values of tomato juice. In the samples of organic and conventional tomato juice there was also measured the content of biologically active compounds such as vitamin C, flavonoids and phenolic acids. An important addition to the assessment of tomato juice value was sensory testing of the product obtained. A sensory profiling method was used to compare the juice of two

production systems (organic and conventional). The results showed that the conventional juice, in comparison with the organic one, received higher marks in sensory evaluation for most of the taste and aroma characteristics examined. This phenomenon may be connected with a different content of polyphenolic compounds and glutamic acid in the tomato juice studied. The conventional juice contained significantly more glutamic acid and considerably less polyphenols (flavonoids and phenolic acids). Glutamic acid largely determines the intensity of typical "tomato flavour" [3], [14], [16]. However, when it comes to sensory perception polyphenolic compounds are substances of bitter taste. Perhaps this is why the conventional tomato juice samples were better evaluated by a sensory panel as those presenting more "typical taste of tomato" and less bitter. In the following paper **[H4]**, both in the study on the raw material quality and in the analysis of the antioxidant content, the HPLC method was applied. According to the results, processing of Rumba F_1 and Mercury F_1 varieties into pulp during juice preparation led to changes in the content of polyphenolic compounds in the final products. As shown in the paper **[H2],** tomato fruits contained only two phenolic acids: gallic acid and chlorogenic acid, and numerous flavonoids: quercetin and its derivatives, kaempferol and myricetin. In addition, in tomato juice there was also determined p-coumaric acid; moreover, the change in flavonoids composition took place. There were only detected quercetin derivatives: quercetin-3-O-rutinoside and quercetin-3-O-glucoside. At the same time, it was observed that the use of other varieties for juice production had a significant impact on the sensory evaluation of tomato juice. In the paper **[H4]** organic tomato juice, as compared with the conventional one, obtained significantly higher sensory marks for sweet aroma, tomato and sweet taste, colour, density, palpability of fruit particles and overall quality.

The effect of growing conditions on the nutritional value and the content of bioactive compounds in pepper fruits

publications [H5] and [H6]

Hallmann E., Rembiałkowska E., Szafirowska A., Grudzień K. 2007. **Significance of organic crops in health prevention illustrated by the example of organic paprika (*Capsicum annuum*)**, Roczniki PZH, v. 58, i. 1, p. 77-82

Hallmann E., Rembiałkowska E. 2012. **Characterization of antioxidant compounds in sweet bell pepper (*Capsicum annuum* L.) under organic and conventional growing systems**, Journal of the Science of Food and Agriculture, v. 92, i. 12, p. 2409-2415

The other solanaceous vegetable covered by the research was pepper. The publication **[H5]** discusses the problem of the quality of organic and conventional pepper fruits in Poland. The experiment was carried out under controlled conditions of the certified organic farm and the corresponding conventional farm. The main objective of the experiment was to compare the nutritional value and the content of bioactive compounds in organic and conventional pepper fruits. Additionally, it was checked whether the methods of soil mulching (covering) used in organic pepper growing had an impact on biological value of the fruits. One variety of sweet pepper Roberta F_1 was selected for the experiment. This variety was grown on certified experimental fields of the Institute of Horticulture in Skierniewice. The following methods of soil mulching were applied: fabric and straw, and the control in the form of uncovered soil. The research methods applied helped to demonstrate the differences in the nutritional value of fruits from specific experimental combinations. Pepper from organic plots was characterized by a significantly higher content of quercetin-3-O-rutinoside (31.92 mg/100 g fw), lutein (5.45 mg/100 g fw) and beta-carotene (3.43 mg/100 g fw) compared with conventional pepper. Only two carotenoids that occurred in the free form were determined in the pepper fruits. They were lutein and beta-carotene. The conducted studies allowed the following conclusion: in field pepper growing under organic system the best method used was plant mulching with straw, when the considered quality classification was the fruits biological value, not the yield. When the plants were mulched with straw, the pepper fruits had the highest content of dry matter, reducing sugars, and beta-carotene.

The occurrence of over 22 different carotenoids was acknowledged in the pepper fruits [8]. Only a few of them exist in the free form, while the others are in the ester form. To be able to proceed with the carotenoids present in the form of esters, one has to use much more advanced analytical methods. Therefore, the development of analytical methods and detailed qualitative and quantitative analysis of carotenoids and polyphenols have been studied in the next publication. In comparison with the previously discussed article, in the paper **[H6]** research conditions were modified by selecting organic and conventional cultivation in production farms. It was a conscious change of the experiment location. From the point of view of the consumer, the nutritional value of pepper produced in real farms is more important than the value of the plants grown on experimental plots. Therefore, the pepper tested was grown in the same conditions as the pepper that every consumer of organic and conventional vegetables can buy. The experiments embraced three pairs of farms, located close to each other, so as to – like in the case of tomatoes growing – eliminate climate and soil

differences which may have had uncontrollable effects on yield quality **[H2].** Three pepper varieties: Roberta F_1, Spartacus F_1 and Berceo F_1 were subject to the study. The applied advanced analytical methods allowed a very accurate qualitative and quantitative analysis of polyphenols, with their specific division into the compounds of flavonoids and phenolic acids. Two phenolic acids, i.e. gallic acid and chlorogenic acid, and six flavonoid compounds, such as quercetin rutinoside and glycoside, myricetin, quercetin, kaempferol and luteolin, were identified and determined in the pepper fruits. In the case of carotenoids, there were determined 11 of 22 carotenoids found in the pepper fruits: beta-carotene, alpha-carotene, cis-beta-carotene, capsorubin, cryptoflavin, beta-cryptoxanthin, antheraxanthin**,** lutein, cis-zeaxanthin, capsanthin and cryptoxanthin. In order to minimize the risk of analytical error, determination was performed on the lyophilisate, as the water content in pepper fruits is sometimes variable, which makes it difficult to interpret the figures obtained. In addition, this procedure minimized the risk of losses, particularly in case of carotenoids in the course of oxidation during the analytical work, since the extraction process and preparation of samples for HPLC analysis took 48 h; the sunlight and oxygen cause rapid disintegration of carotenoids, especially when working with fresh fruits. The use of lyophilisate, sample darkening and low temperature contributed to the protection of carotenoid compounds during a long analysis time. Regardless of the variety, the organic pepper was characterized by a significantly higher content of dry matter, vitamin C, total carotenoids, beta-carotene, alpha-carotene, cis-alpha-carotene, and phenolic acids such as gallic acid and chlorogenic acid, as well as flavonoid compounds (quercetin and its derivatives) and kaempferol. According to the studies conducted, the pepper varieties tested were significantly different from each other in terms of the content of biologically active compounds. It is worth noting that the authors of the paper not only showed the differences in the content of bioactive compounds and compared them with the data available in the world references, but also tried to explain the phenomena that contributed to the occurrence of these differences.

The effect of raw material sourcing and processing on the nutritional value and the bioactive compounds content in pickled pepper

publications [H7] - [H9]

Rembiałkowska E., **Hallmann E**. 2008. **The changing of bioactive compounds in pickled bell pepper fruits from organic and conventional production**, Journal of Research and Applications in Agricultural Engineering, v. 53, i.4, p.51-57

Hallmann E., Rembiałkowska E. 2009. **The influence of pasteurization process and storing on bioactive compound content in pickled red pepper fruits from organic and conventional production**, Journal of Research and Applications in Agricultural Engineering, v. 54, i.3, p. 90-95

Hallmann E., Rembiałkowska E. 2001. **The content of selected antioxidant compounds in selected bell pepper varieties from organic and conventional cultivation before and after freezing process**. Proceedings of the 2th Scientific Conference of the International Society of Organic Agriculture Research (ISOFAR) (Neuhoff et al. eds.). Modena, 18-20 June, v 2, 802- 805

The main direction of pepper processing in Poland is pickling and freezing [26]. Pepper fruits intended for processing must comply with a number of quality requirements. What really counts, besides the size classification, the lack of damage caused by pests and diseases and the absence of mechanical damage, is high quality of raw material. Only fruits of high nutritional value guarantee a product of high quality. Pickled pepper is a specific product of very low pH level. Acidification of the product ensures discontinuation of the growth of putrefactive bacteria that cause fruit tissue decomposition. At the same time, it was observed that at lower pH level flavonoid compounds are more available than at pH close to neutral [21], [25]. As shown in the publication **[H6]**, sweet pepper fruits represent a good source of flavonoids, in particular myricetin, quercetin and its derivatives (quercetin-3-O-rutinoside and quercetin-3-O-glucoside). The following paper presents the content of bioactive compounds in freshly prepared pickles made from organic and conventional pepper, which is then compared with unprocessed pepper fruits **[H7]**. For the experiment there were selected two varieties of sweet pepper: Ożarowska F_1 and Roberta F_1. For the purposes of the experiment, pepper was grown in two adjacent farms (certified organic and conventional ones), and just as in the case of the publication [**H6]**, the farms were located close to each other to avoid the influence of uncontrolled climate and soil conditions. The collected data showed that the pickling process changed the chemical composition and sensory characteristics of the final product obtained. The content of dry matter as well as total and reducing sugars decreased, while the acidity of both organic and conventional products increased significantly. Unfortunately, the content of vitamin C in all samples of pickled pepper diminished as well. This phenomenon could be associated with "osmotic displacement" of vitamin C from fruit pieces to acetic pickle being the environment of a higher acidity in comparison with the acidity of fruit pieces [9]. During the preparation of the samples for the study, there were used only the fruits of pickled pepper, with no pickle liquid, which could be the reason of lower levels (or losses) of vitamin C in the pickles as compared with the fresh fruits. At the same time, during the preparation of pickles pepper fruits were exposed to oxygen (during fruit

cutting), which also may have contributed to the decrease in the content of vitamin C in the pickled product. But ultimately, the organic pickled pepper had more vitamin C than the conventional one. The pickling process contributed to changes in the content of flavonoids, but some discrepancies were observed between the varieties tested. What is also interesting is that the conventional pickled pepper fruits contained more beta-carotene compared to the organic fruits, although in fresh fruits the content of this compound was similar both in organic and conventional samples. Organic fresh pepper was characterized by a higher content of lutein as compared with the conventional samples. Having analysed the results of sensory studies, it was found that organic pickled pepper received higher quality marks for pepper and seasoning aroma as well as for hot, pepper and sweet taste, and for the overall quality. Another important aspect of pepper processing is pasteurization of the product and its storage. The aim of pasteurization is to preserve the biological purity of the pickle produced, while the storage indicates the time that elapses from the moment of its production, through distribution chain, until delivery to consumers. And exactly these aspects were subject to the studies discussed in the article **[H8].** In the paper, there were compared the products (pickled pepper of two different varieties: Roberta F_1 and Berceo F_1 from organic and conventional production) immediately after the pickles preparation (fresh products), the pickles after pasteurization and the pickles after six-month storage. The processes of thermal preservation and storage of the product affected adversely the content of vitamin C. In case of the content of total flavonols, phenolic acids, and beta-carotene, the organic samples immediately after the pickles preparation contained more of these compounds than the conventional ones. Simultaneously, there was observed negative impact of heat treatment and storage time on the content of these compounds in pickled pepper. After the pasteurization process, only in the case of lutein there was not recorded any decrease in the pigment content in all pickle samples tested. This phenomenon can be explained by a much greater thermal stability of lutein as compared with beta-carotene and lycopene [15].

Freezing of vegetables is a good way to preserve their nutritional value. It is a process that interferes least with the chemical composition of vegetables. Unfortunately, numerous vitamins, especially vitamin C, are very sensitive to thermal methods of raw materials and products preservation used in food processing industry. The use of blanching, which precedes the rapid pepper fruits freezing, has contributed significantly to the conservation of vitamin C as compared with unblanched fruits [5]. In the following paper presented **[H9]** an attempt has been made to assess how freezing affected the content of antioxidant compounds in organic

and conventional pepper fruits. Two varieties of sweet pepper, i.e. Ożarowska F_1 and Roberta F_1 were selected for the experiment. The content of carotenoid compounds, flavonoids and vitamin C was determined in fresh fruits (before freezing) and after the period of frozen fruit storage at -20^{o}C. Although the freezing is one of the better preservative processes, an average beta-carotene decline by 50% of the initial value (determined in fresh peppers) was observed in frozen fruits, both organic and conventional, and in both varieties tested. There was also recorded an increase in the content of lutein in 100 g of the product by 14% on average for all pepper combinations tested. Changes in carotenoids content can be explained by diverse thermal stability of the pigments: beta-carotene and lutein. Fruits after freezing get a much "lighter" colour compared to the one of fresh fruits. It is associated with a higher proportion of yellow colour (lutein), and a decreased share of orange and brown colour (beta-carotene). The vitamin C content after freezing decreased in all samples tested. It should be noted, however, that organic pepper before freezing was characterized by a much higher content of vitamin C in fruits as compared with the conventional pepper. Therefore, even if a decrease in the vitamin C content in all samples tested took place, it was still organic pepper which contained more vitamin C compared with the conventional one. A similar phenomenon was observed in the case of flavonols. The content of rutin (after freezing) was lower as compared with fresh fruits for both organic and conventional varieties tested, but the organic pepper had a higher final content of rutin in the fruits.

5.5. Summary of single-topic series of publications entitled: "Comparison of the nutritional value and the content of bioactive compounds in selected nightshade (*Solanaceae*) family vegetables from organic and conventional production systems, including processing elements"

As a result of the studies presented and supported by publications, research hypotheses – as initially made – have been confirmed. It has been shown that fresh tomatoes and peppers harvested from organic farming had a higher nutritional value, since they contained more antioxidant compounds as compared to the vegetables produced by conventional methods. The second positively verified hypothesis was proving that the tested varieties of tomatoes and peppers differed from one another in terms of biologically active compounds content; these features were genetically conditioned, as they occurred regardless of the cultivation system used. At the same time, there has been observed a strong effect of the growing year (season) on the content of bioactive compounds in the nightshade vegetables. The studies confirmed that the products obtained from processing of nightshade vegetables, i.e. tomato juice and pickled and frozen pepper, had a different chemical composition compared with the

unprocessed vegetables. An advanced analytical technique used to evaluate the content of biologically active compounds facilitated learning and understanding of the relationships between separate compounds, rather than their groups, which made in-depth interpretation of the differences possible.

5.6. Statements

Meeting the paper's objective and verifying the hypotheses made at the outset allowed formulating of the following statements**:**

- the method of cultivation (organic and conventional) had a significant impact on the nutritional value of fresh nightshade vegetables;
- nightshade plants from organic farming have a higher content of vitamin C and bioactive compounds from the group of polyphenols and carotenoids as compared to the conventional ones;
- with regard to the quality of the raw material, an important element of the organic farming success is proper selection of vegetable varieties;
- processing of organic and conventional raw materials is an important action taken to maintain the continuity of tomato and pepper consumption in Poland;
- proper selection of raw materials for processing ensures obtaining products of high biological value;
- the application of advanced analytical techniques to assess the content of bioactive compounds in the fruits of tomato, pepper and their products gives a detailed picture of the differences between the raw materials and products from organic and conventional systems.

5.7. Final conclusion

The presented studies of the nightshade vegetables from organic and conventional production contribute to deepening the understanding of the impact of different cultivation systems, in particular organic system, on the nutritional value and the content of bioactive compounds in nightshade vegetables in Polish agrotechnical conditions. The research problems are a valuable contribution to the knowledge on the quality of organic and conventional vegetables. Due to high biological value and antioxidant compounds content in

the discussed organic nightshade vegetables and their products, the consumption of these vegetables and products may contribute to promoting of health, especially in the light of the spread of chronic non-communicable diseases.

6. The history of scientific work with the overview of other scientific publications

I became a student of the Faculty of Horticulture, the Warsaw University of Life Sciences (SGGW) on October 1, 1994. After five years of studies, I received Master of Science in Engineering degree by presenting a research paper entitled: *"Assessment of the level of glutathione and ascorbate as antioxidant system components in selected genotypes of Brassica vegetables"*. The thesis was assessed as very good (A grade), and having passed the MSE exam I graduated from the university with very good mark on the diploma. At the same time, in 1997, I began the studies at the Parallel Teacher Training College at the Faculty of Economics and Agriculture, SGGW. After graduating from the college, I was granted the right to teach the young and adults in disciplines as learned at the basic studies. In 1999, I began Doctoral Studies at the Faculty of Horticulture and Landscape Architecture (formerly Faculty of Horticulture), and four years later I presented a scientific dissertation entitled: *"The estimation of yield and the fruit quality of three selected types of tomato grown on mineral wool"*. My dissertation was assessed as very good, and having passed all exams along with public viva voce exam I received PhD in Agricultural Sciences in the field of vegetable farming.

I began my professional career on October 1, 2005 as a senior lecturer in the Chair of Organic Food at the Faculty of Human Nutrition and Consumption Sciences. Since that moment I have started scientific and teaching work related to broadly defined research on the nutritional value of organic and conventional vegetables and fruits and their products.

In addition to issues concerning the nutritional value and the content of biologically active compounds in the nightshade vegetables and their products, as presented in a scientific achievement being the basis of the habilitation application, I have carried out a number of research mainly on the broadly defined qualitative analytics of vegetables, fruits and their products, as well as on the effects of bioactive compounds on animal health. Research and scientific topics I investigate include the following:

6.1 **Focus group 6.1**.: The influence of cultivation method on antioxidative compounds in tomato and bell pepper fruits from organic cultivation and suitability of the vegetables for processing, publications no.: [P3], [P11], [P2], [P36], [P13], [P6], [P4], [P23], [P44], [P24], [P18], [P31];

6.2 **Focus group 6.2.:** Analysis of bioactive compounds in apples and their preservers including cultivars origin and processing method, publications no.: [P1], [P45], [P10], [P8], [P9], [P12], [P15], [P17], [P22];

6.3 **Focus group 6.3**.: The influence of cultivation methods on nutritive value and antioxidative compounds content in selected radical vegetables and their preservers from organic and conventional production, as well as the estimation of thermal processing in time of vegetable juice production, publications no.: [P25], [P41], [P16], [P19], [P34], [P32], [P33], [P45], [P47], [P53], [P33];

6.4 **Focus group 6.4.**: The evaluation of analysis methods for bioactive compounds measurement in medicinal plants and spices including production methods, publications no.: [P38], [P39], [P46], [P52];

6.5 **Focus group 6.5**.: The characterization and measurement of antioxidative compounds in cultivated berries fruits as well as in fruits from natural state and their preservers, publications no.: [P21], [P27], [P28], [P30], [P49], [P50], [M3];

6.6 **Focus group 6.6**.: The estimation of bioactive compounds in vegetables used for animal feed production as well as the possible influence of organic and conventional animal feed on well-being of animals, publications no.: [P29], [P51], [P55].

Research subject matter specified in **6.1** concerned the impact of different cultivation techniques on the chemical composition of tomato fruits. Sweet pepper fruits were another object of the study. In this series of publications (other than those included in the major scientific achievements) there are also included issues concerning the impact of processing operations on the final quality of tomato and pepper products. In addition, among the publications one can find a monographic article discussing the origin and health properties of tomato and pepper, taking into account the impact of organic and conventional farming methods on the fruits quality and yield [M2].

One of the most important elements of growing tomatoes under cover is proper selection of the substrate. The most common substrates used in Poland include mineral wool and coconut mat. When properly selected, they guarantee good yield of high biological value fruits. Another factor affecting these parameters is fertilization. A particularly important element in tomato cultivation is nitrogen, which is defined as the yielding element. Tomato is a great source of numerous compounds of antioxidant activity (like carotenoids, polyphenols or vitamin C), but also of macro- and micronutrients, especially potassium and magnesium. The experiments described in the publications **[P3], [P11], [P2]** and **[P35]** refer to the above-described impact of alternative substrates and the level of nitrogen fertilization on the nutritional value of tomatoes grown under cover. When tomatoes were grown on mineral wool, especially in the spring-summer cycle, a higher content of nitrogen and calcium was found in tomato fruits; the fruits of the plants grown on a coconut substrate had a significantly higher content of phosphorus and magnesium. Some changes in tomato fruit macronutrients content were acknowledged in autumn cycle. The plants grown on coconut substrate were characterized by a higher content of nitrogen, phosphorus, potassium and calcium as compared with the fruits obtained from plants grown on mineral wool **[P3].** The level of yield and its quality are determining factors for choosing a method of tomatoes under cover growing. Mineral wool facilitates the increase in crop yields, however, the issue of the fruits quality remains disputable. Thus, the quest for alternative crop substrates has begun. By using a coconut fibre substrate one can obtain fruits of a higher nutritional value, but of a lower yield. In the experiment presented in the publication **[P11]** there was examined the effect of coconut substrate on the biological value of the fruits of two small-fruits tomato varieties, i.e. Conchita F_1 and Favorita F_1, and one standard variety – Cunero F_1. The results clearly indicate that tomatoes (regardless of the variety tested) grown on coconut fibre mats were characterized by a higher content of dry matter, vitamin C, beta-carotene, lycopene and flavonols as compared with those grown on mineral wool.

The level of nitrogen fertilization had a significant effect on the accumulation of microelements in the fruits of tomato varieties tested. With the use of variable nitrogen fertilization (140/210 mg/L), in the spring-summer cycle and on mineral wool, it was found that tomato fruits accumulated more phosphorus, potassium and calcium, while in the autumn cycle higher levels of calcium and magnesium were recorded in the fruits obtained from the plants grown at low nitrogen fertilization (140 mg/L). The highest phosphorus content was found in the fruits grown at constant high-level nitrogen fertilisation (210 mg/L). An

important indicator of production profitability for producers is the yield level, therefore they opt for cultivation on mineral wool [**P2]**. A major problem in this type of cultivation is the substrate residue after the end of the crop cycle. Mineral wool is difficult for recycling (as it is melted and processed basaltic rock). Thus, it remains after cultivation, posing a heavy burden on the environment. The problem is exacerbated especially in countries where the cultivation of tomatoes under cover takes place on a massive scale (the Netherlands). It turns out that under cover tomatoes can be grown on natural substrate, without the need for alternative substrates [**P35]**. Organic fertilization is an important component used in organic farming, and as already underlined in the presented papers of the habilitation dissertation, it has a significant impact on the quality of tomato yield. However, not only the method of fertilization and the fertilizer dose, but also the time of growing has a significant impact on the yield level and nutritional value of tomato fruits. A long-term use of organic fertilizers to grow tomatoes under cover helps to stabilize the soil, produce a rich sorption complex and develop soil microflora and microfauna. With such a soil condition, there occurs uniform decomposition of soil organic matter and the release of macro- and micronutrients to the sorption complex, which then is used by tomato plants during the growing season. In the experiment described in the publication **[P35]** tomatoes were grown using three combinations of organic and mineral fertilization: ORG (organic fertilization with straw); ORGWS (organic fertilization without straw) and CONV-S (mineral fertilization in soil). The relationships between biologically active compounds in tomato fruits (beta-carotene, lycopene, flavonoids, sugars and organic acids) and macro- and micronutrients in the soil were determined. The results showed that the content of beta-carotene in the fruits was heavily dependent on a low dose of nitrogen, calcium, and magnesium. In case of quercetin, a strong positive correlation with the macroelements such as potassium and phosphorus was observed. The yield level from all fertilization combinations was very close to each other. In the research summary it was proved that a three-year cultivation system is too short for proper biological stability of the plant root environment. Organically fertilized soil needs more time to enter into a state of stability, in which the collection of ions occurs much more efficiently, and the result is a significant increase in the yield from organically fertilized system as well as a higher biological value of tomato fruits. In subsequent publication **[P14]** there was analysed the effect of cultivation in an unheated tunnel and field farming (both in organic and conventional systems) on nutritional and sensory values of tomato fruits. In the paper [**P14]** four varieties of standard field tomatoes were examined: Rumba F_1, Juhas F_1, Kmicic F_1, and Gigant F_1, and one small-berry variety Koralik. A significant influence of cultivation method on the

biological value of tomato fruits was ascertained. The organic tomato fruits had a significantly higher content of dry matter, total and reducing sugars, organic acids, beta-carotene, vitamin C and quercetin as compared with tomatoes grown in the conventional field, which were richer in lycopene. The following publication [**P6]** tackles the issue of assessing nutritional value of tomato fruits of different varieties from organic and conventional farming, and the content of biologically active compounds, taking into consideration the harvesting time. Three varieties of standard tomatoes, i.e. Atol F_1, Awizo F_1 and Etna F_1, and two small-berry varieties – Piko F_1 and Koralik – were selected for the experiment. The same varieties were grown in a certified organic field in Skierniewice and in an experimental conventional field located in the neighbourhood. Fruit quality analyses were performed at the beginning and at the end of tomato plants yielding period. The collected results indicated that organic tomatoes had a significantly higher content of total and reducing sugars as well as vitamin C, regardless of the harvesting time, compared with conventional fruits which contained significantly more lycopene in all fruits, regardless of the time of harvesting. The content of beta-carotene was significantly higher in organic fruits and only at the first time of harvesting, i.e. at the beginning of fructification period. Organic tomatoes were also characterized by a higher content of total flavonoids in comparison with the conventional ones. The publication [**P4]** discusses the impact of soil covering on the nutritional value of field tomato variety, such as Etna F_1, and small-berry varieties Piko F_1 and Koralik, as well as sweet pepper variety Roberta F_1 in organic and conventional farming. The collected results showed that organic tomato fruits were characterised by a significantly higher content of beta-carotene, vitamin C, quercetin and dry matter, irrespective of the litter type and variety tested. And in the case of organic pepper, the best method was mulching the plants with straw. In this combination pepper fruits had the highest content of dry matter, flavonoids, beta-carotene and vitamin C as compared with the fruits of the plants mulched with other horticultural materials.

Tomato juice is one of the most readily consumed vegetable juice on the Polish market. In 2012, it was in the fifth place among a group of juice consumed by consumers. Tomato juice retains many valuable tomato properties, but also thanks to fruits processing it gains new features that the fresh tomatoes are lacking in. Owing to thermal processing of fruit pulp, during the juice preparation a change in the configuration of lycopene from *all-trans* to *all-cis* form takes place. This increases significantly the lycopene bioavailability to humans. In the publications **[P23]** and **[P43]** the nutritional value of tomato juice from organic and conventional production and the effect of thermal treatment on the final quality were assessed.

Freshly prepared organic tomato juice was characterized by a significantly higher content of dry matter, vitamin C, lycopene and flavonoids in comparison with conventional juice which was richer in beta-carotene and glutamic acid. The publication **[P43]** proves that organic tomato juice had a significantly higher content of reducing sugars and lycopene, and a slightly higher content of L-ascorbic acid and beta-carotene in comparison with the samples of conventional juice. At the same time, it was observed that organic tomato juice was characterized by higher contents of total phenolic acids and flavonols, whereas the compounds of flavanones group were present in greater amounts in conventional juice. The pasteurization process contributed to an increase in the content of dry matter, reducing sugars, organic acids and free amino acids in the samples of tomato juice. The fresh samples from conventional farming had a higher content of p-coumaric acid and naringin, while other phenolic compounds identified were more abundant in organic tomato juice. Fresh juice pasteurization process contributed to changes in the content of phenolic acids, especially gallic and p-coumaric acids, and other flavonoid compounds.

Another series of publications concerned the nutritional value of organic and conventional pepper as well as the selected aspects of its processing. In the publication [**P18]** two varieties of sweet peppers Ożarowska F_1 and Roberta F_1 were chosen for examination. The experiment was conducted in two certified organic farms and in two neighbouring conventional farms. The method of cultivation significantly affected only the content of vitamin C. The varieties used for the experiment reacted differently to the applied method of cultivation. Regardless of the type of cultivation, the variety Ożarowska F_1 was richer in vitamin C and flavonoids. Under the conventional system, Roberta F_1 produced more dry matter in the fruits. The publication [**P24]** discusses the impact of pickling process on the content of bioactive compounds in large bell peppers. Pepper varieties discussed in the publication [**P18]** were subjected to pickling, then the content of antioxidant compounds was assessed and the sensory evaluation of the product was carried out. Pickling process changed the chemical composition of pepper, though organic pickled pepper still contained more vitamin C compared with the conventional one. In the sensory evaluation organic pepper gained a higher mark for sweet taste and overall desirability. There was also recorded a strong correlation between the content of flavonoids and hot taste, especially in conventional samples.

Topics addressed in 6.2. involved a comprehensive analysis of bioactive compounds in apples, including their origin and the impact of various processing operations on the value of puree and apple juice. Poland is one of the most important producers of apples in

conventional system in Europe, with an annual production of 2,800 thousand. tons in 2012 [23]. Fresh apples are readily eaten by consumers and they represent a valuable raw material for processing. They are used to produce clarified and cloudy juice, purees, mousses, jams, chips, or wine [26]. Apple juice is one of the most frequently consumed by Polish consumers (14.3%), following multi-vegetable (21.0%) and orange juice (24.6%) [1]. Organic orchards and berry plantations account only for 13.3% of the total organic plant production in Poland [22].

In the publication [**P1]** the experiment included three varieties of apples: Jonagold, Cortland and Lobo. Apples were grown in two production orchards: organic and conventional. The contents of biologically active compounds were determined and sensory characteristics assessed in the apple fruits. All tested varieties of apples were characterized by a significantly stronger skin colour and were better rated by consumers when they came from organic production. When it comes to evaluation of different varieties, Cortland apples received very high marks for palatability and overall quality, but only when they derived from organic orchard. For the other varieties, no significant differences in sensory evaluation were found. Organic apples of Cortland, Lobo and Jonagold varieties contained significantly more vitamin C, flavonoids and anthocyanins as compared with conventional apples. The publication [**P44]** extends the research problem, as compared with the previously presented studies. The results of examination related to a long-term (three-year) experiment; moreover, a greater number of analyses showing the nutritional value of fruits was performed. The results collected indicated that there were no significant differences in sensory evaluation between organic and conventional apples. However, organic apples had a higher content of sugar extract and total and reducing sugars compared with the conventional ones. Not only the cultivation method (organic and conventional), but also the origin of apples (new and old varieties) had a significant impact on the content of biologically active compounds in the fruits. In the publication [**P10]** the fruits of old and new apple varieties were tested. Old variety apples contained significantly more antioxidant compounds (flavonols, anthocyanins, and vitamin C). A variety containing the highest level of dry matter, flavonols and vitamin C among the old varieties was Grafsztynek Inflancki. Among the new varieties, the highest nutritional value was typical for the following varieties: Idared (high content of dry matter and vitamin C), Jonagold (high content of flavonols) and Cortland (high content of anthocyanins). Apples represent a very good raw material for processing. The following products can be obtained from apples: juice, purees, mousses, creamogen, dried fruits, and chips. Other papers are

devoted to assessing the content of bioactive compounds in apple juice and creamogens and to the influence of technological factors and storage time on the quality of the final product [**P5**], [**P8],** [**P9**], [**P12**], [**P15**], [**P17**], **[P22].** The gathered material and the analyses made it possible to demonstrate that purees produced from organic apples were characterized by a higher content of polyphenolic compounds in comparison with conventional products, and similarly as fruit purees made from old apple varieties they were richer in antioxidants. The pasteurization process contributed to the decrease in the content of bioactive compounds in apple products (juice and creamogen). Storing of pasteurized apple juice and purees fostered further decline in biologically active compounds as compared with freshly prepared and pasteurized products.

As part of the topic described in p. 6.3., the studies on the impact of cultivation methods and processing operations on the quality of selected root vegetables and their products have been undertaken. Root vegetables (beets and carrots) occupy an important place among the five most important species of field vegetables grown in Poland. In 2012, the area of conventional carrot cultivation was 30 thousand. ha, with the yield of 840 thousand sets. tons. Production of beetroot is ranked fourth among field vegetables. It is cultivated on the area of 22 thousand. ha, and the yield in 2012 reached 345 thousand up. tons [23]. Unfortunately, organic beet and carrot cultivation represents only a small percentage of the total production of these vegetables. A comparison of the effect of cultivation system (organic and conventional) on the nutritional value of beet roots with specific regard to the content of bioactive compounds in red beets was the scope of the research presented in the publications [**P25**], [**P41**] and [**P47]**. The collected results indicate that both method and year of cultivation had a significant effect on the accumulation of biologically active compounds in the roots of red beets. Organic beetroots had a significantly higher content of vitamin C in comparison with the conventional ones. However, when it comes to polyphenolic compounds, a substantial effect of cultivation method was observed only in the first year of the experiment [**P25]**, while in the second year the differences were not statistically significant. The second vegetable tested was carrot. The publications **[P16], [P19]** and [P35] discuss the impact of cultivation method on the biological quality of carrot roots, and in the publications [**P32**], [**P33**], [**P45]** and [**P53]** there is described the impact of carrot processing conditions, selection of appropriate varieties and methods of thermal preservation of the product on the final quality of carrot juice. The studies showed that organic carrots contained significantly more reducing sugars, beta-carotene and lutein in roots compared to conventionally grown carrots. The varieties of carrots used for the

experiment differed from each other. Regardless of the cultivation type, the variety Perfekcja F_1 was richer in sugars and beta-carotene, while the conventionally grown variety Flacoro F_1 contained more dry matter and lutein in the roots. Carrot juice enjoys great popularity among consumers. In 2012, it was second in the ranking of consumption by Polish consumers (21%), following orange juice (25%). In third place was apple juice (14.3%) [1]. Based on the studies conducted it was ascertained that there were differences in nutritional value between juices from organic and conventional production. The fresh organic carrot juice tested had significantly higher total acidity and contained slightly more dry matter and reducing sugars as compared to conventional juice. In turn, conventional juice had a significantly higher content of phenolic acids and vitamin C, and contained slightly more beta-carotene and lutein. Pasteurisation of carrot juice, both organic and conventional one, contributed to the increase in the content of dry matter and reducing sugars, higher acidity and a greater content of lutein; the content of total sugars, phenolic acids, beta-carotene and vitamin C was reduced. The selection of variety is a very crucial factor in the production of carrot juice and it may materially affect the quality of the juice obtained. The discussed publications examined separately carrot juice made from Perfekcja F_1 and Flacoro F_1 varieties. Carrot juice manufacturers often opt for the variety Flacoro F_1 because of the good quality parameters of roots (which are equal-size and large). However, the research on quality aspects indicates that the variety with higher levels of beta-carotene, total and reducing sugars was Perfekcja F_1. The above-described characteristics should determine the variety suitability for processing more competently than physical characteristics of roots. After pasteurization process, the change in the content of total and reducing sugars, dry matter, acidity and vitamin C in the juice samples was discovered.

Another research topic discussed in a set of publications 6.4. concerns a broadly-defined issue of biologically active compounds in herbal raw materials and spice plants. The publications [**P38**], [**P39**], [**P46]** and [**P52]** present extraction methods and the impact of growing conditions on the content of polyphenols and carotenoids in herb species such as: lemon balm (*Melissa officinalis* L.), peppermint (*Mentha piperata* L.), lovage (*Levisticum officinale*), sage (*Salvia officinalis* L.), thyme (*Thymus vulgaris*) and rosemary (*Rosmarinus officinalis*). In addition, the effect of cultivation method (organic and conventional) on the quality of herbal raw material was examined. The collected results indicate that the method of cultivation had a significant impact on the content of polyphenols in the herb species tested. In the group of spices, thyme and sage, which contained significantly more vitamin C and flavonoids, as well

as rosemary, which was rich in phenolic acids, deserved particular attention. Summarising the research on spice plants, it should be pointed out that herbs, especially those from organic production, should represent a regular part of our diet. They contain a lot of valuable antioxidant compounds that protect the consumer's body against a number of chronic non-communicable diseases.

The publications included in 6.5. focused on assessing the content of bioactive compounds in berry fruits (black currant, chokeberry, blueberry, blue huckleberry, raspberry, wild strawberry and blackberry), and in the fruits obtained from natural state (mountain ash, Japanese quince, rugosa rose and Siberian crabapple) **[P49], [P50]** and **[M3]**. Berries are a great source of anthocyanin and flavonoid compounds. Undoubtedly, chokeberry fruits include the highest content of anthocyanins – up to 1500 mg/100 g fw. Despite the high content of bioactive compounds in chokeberry, the fruit is underestimated by consumers. Chokeberry fruit and its products (e.g. juice) have a very tart and bitter taste. It is associated with a very high tannin content in fresh fruits. Therefore, prior to consumption, it is recommended to freeze the fruits. This process contributes to degradation of tannins and polysaccharides, and thus significantly improves the taste of the fruits. In processing industry, chokeberry is used more as a supplement to other juices with bland or sweet taste to improve their sensory quality. That is why consumers choose more eagerly mixed juice (such as apple and chokeberry or pear and chokeberry) rather than pure chokeberry juice. Among the remaining berries, blueberry, blackberry and raspberry deserve particular attention. Among the fruits harvested from natural state, it is worth to look into rugosa rose more closely, the fruits of which contain up to 150 mg/100 g fw of vitamin C and as much as twenty times more lycopene in comparison with tomatoes. There was also assessed the impact of cultivation method (organic and conventional) on the content of bioactive compounds in black currant fruits and products **[P21], [P27], [P28], [P30]** and **[P37].** In the publications it was found that the content of polyphenolic compounds in black currant fruits depended considerably on cultivation system and the variety tested. Organic currants had a significantly higher content of flavonoids, anthocyanins and vitamin C compared with conventional fruits.

The last issue classified in 6.6. was the assessment of the content of bioactive compounds in vegetables for animal feed production, the compounds content in the feed and the impact of organic and conventional nutrition on animal welfare. The feed for animals raised in organic system must be produced in compliance with all guidelines on organic farm practices. As shown in previous publications, organic management system has affected significantly the

content of bioactive compounds in vegetables and fruits. Organic processed raw materials also maintained a higher biological value as compared to conventional products, although the processing methods described changed the final composition of the product. A very essential stage in the operation of organic farm is animal production. Animal feed has a significant impact on health parameters. The publications [**P14**], [**P29**], [**P51]** and [**P55]** show that feeding rats with organic fodder affected their growth parameters, hormone balance, body composition, and the immune response. The organic feed differed considerably in the content of bioactive compounds in comparison with the conventional one. Based on these facts, one can make a hypothesis that the level of bioactive substances in laboratory animal feed may affect the functioning of the animal body, including the endocrine and immune systems. This hypothesis requires further investigation.

7. Summary overview of the research work

In summary overview of other studies conducted by the habilitation candidate and documented in the list of publications, the origin of tomatoes and peppers has been presented; it has also been revealed how cultivation factors (i.e. fertilization, cultivation system, substrate and agrotechnical conditions) may affect the nutritional value of fruits, especially the content of biologically active compounds in organic agricultural crops. The studies on the effects of processing conditions on the final quality of the products made from organic and conventional tomatoes and peppers have been carried out as well. Apples and their products are very popular among Polish consumers, which is why the issues of fruit quality, nutritional value and content of biologically active compounds are discussed in the second thematic group of other research. Organic apples were richer in biologically active compounds as compared to the conventional ones. Apples of past (old) varieties are recommended for organic growing due to better plants adaptation to local climate and growing conditions. Fruits of old apple varieties were characterized by a higher content of bioactive compounds in comparison with fruits of commodity (new) varieties. Products made from apples (juice and puree), both from organic fruits and old varieties, were characterized by a higher biological value as compared to conventional apples and fruits of new varieties. In the following thematic group the nutritional value of organic and conventional root vegetables (carrots and beetroots) and their products (carrot juice) has been discussed. It has been indicated that field vegetables in organic and conventional environments are subject to higher number of agrotechnical factors (soil, fertilizing, watering and insolation) as compared with the controlled cultivation of tomatoes and peppers under covers. Despite difficulties, it has been

shown that organic carrots and beetroots were characterized by a higher biological value than the conventional vegetables. At the same time, it has been demonstrated that a high quality raw material, when it is processed in a proper way, also gives a high quality product. The following thematic group shows the effect of organic and conventional farming methods on the biological value of herbs and spices. It is worth noting that herbal and spice plants from organic production not only had a higher content of bioactive compounds in comparison with the conventionally grown plants, but also exhibited other qualitative composition. Some polyphenolic compounds not present in conventional plants have been found in organic plants. Berries and fruits harvested from their natural state represent a rich source of antioxidant compounds important to health. In a series of publications on chemical composition of these interesting but little-appreciated fruits it has been shown that they can serve as a pro-health supplement to daily consumed food. In the next series of publications on the impact of organic and conventional raw material feed it has been demonstrated that the feed had a positive impact on the body of laboratory animals, and in particular on the endocrine and immune systems. There is also an urgent need to confirm the effect of organic vs. conventional diets on farm animals and human organisms.

8. References

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