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NITRATE CONTENT OF THE EDIBLE PARTS OF VEGETABLES AND SPICE PLANTS

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Abstract. The objective of a study conducted in the years 2007–2008 was to determine the nitrate content of the edible parts of vegetables and spice plants. The analyzed materials consisted of the following species: tomatoes, carrots, sweet basil and marjoram grown in the field, and tomatoes and chili peppers grown in a plastic tunnel. The experiment comprised different cultivation methods, sowing and planting dates, and fertilization levels. Among the analyzed cultivars of field-grown tomatoes, increased nitrate concentrations were observed in the fruits of cv. Złoty Ożarowski. Similar results were noted when eight tomato cultivars were grown in an unheated plastic tunnel. The fruits of cv. Bawole Serce had the lowest nitrate content, compared with the remaining tomato cultivars. Supplemental fertilization of tomato plants grown under cover significantly contributed to nitrate accumulation. The fruits of chili peppers grown in a plastic tunnel had a very low nitrate content. As regards marjoram, the highest nitrate concentrations were reported for the second date of sowing. The average nitrate content of carrot storage roots did not exceed the maximum permissible levels. Supplemental fertilization contributed to an insignificant increase in the $N\text{-}NO_3$ content of carrot roots.

Key words: nitrates, tomatoes, carrots, marjoram, basil, chili peppers, cultivation methods, fertilization

INTRODUCTION

Vegetables are the main source of nutrients, minerals and biologically active components that exert a beneficial influence on human health. However, plant raw materials contain also anti-nutritional compounds, including heavy metals, pesticide residues, nitrates and nitrites. If accumulated in vegetables at high concentrations, due to inadequate growing, transport and storage conditions, these compounds may have serious toxic effects. Depending on the diet, vegetables account for 50 to 80% of total dietary

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nitrate intake [Wojciechowska et al. 2000]. Nitrate accumulation in vegetables is determined by genetic factors (species, cultivar), agricultural conditions (sowing and planting date, harvest time, soil type, fertilization), and climatic conditions. Nitrate concentrations differ also among plant edible parts.

The objective of this study was to determine the effect of genetic factors and agricultural conditions on the nitrate content of the edible parts of selected species of vegetables and spice plants.

MATERIALS AND METHODS

The experiment was conducted at the Experimental Station of the University of Warmia and Mazury in Olsztyn. The experimental materials consisted of the following species grown in the field: tomatoes (*Lycopersicon esculentum* L.), carrots (*Daucus carota* L.), marjoram (*Origanum majorana syn. Majorana hortensis*.), sweet basil (*Ocimum basilicum* L.) and of the following species grown in an unheated plastic tunnel: chili peppers (*Capsicum annuum* L.), tomatoes (*Lycopersicon esculentum* L.).

Under field conditions, vegetables were grown in brown soil of class IVb, with a 2.8% humus content, pH 7.1 in H_2O, and salt concentration of 0.36 $g{\cdot}dm^{-3}$, which contained the following amounts of nutrients: $N\text{-}NO_3$ – 34, P – 90, K – 154, Ca – 2880, Mg – 146, Cl – 16 $mg{\cdot}dm^{-3}$. Soil mineral deficiency was supplemented according to the nutrient requirements of each species [Starck 1997, Sady et al. 2000].

Two tomato cultivars, Bawole Serce and Złoty Ożarowski, were grown in the field, in the control treatment – without mulching, and in soil mulched with black non-woven PP fabric. Tomato seedlings were produced in a greenhouse. The substrate used for seedling production was highmoor peat with the following chemical composition: $N\text{-}NO_3$ – 100, P – 80, K – 215, Ca – 1240, Mg – 121 $mg{\cdot}dm^{-3}$, pH 5.9 in w H_2O, and salt concentration of 1.5 $g{\cdot}dm^{-3}$. The experiment was performed in a randomized block design, in three replications. Ten plants were grown in each plot. The fruits were harvested on ripening. At the stage of full fruiting, 15 fruits were sampled from each plot for chemical analyses.

Six carrot cultivars were analyzed in the study, including four early cultivars (Deep Haze F_1, Florida F_1, Interceptor F_1, Purple Haze F_1) and two late cultivars (Joba, Kazan F_1). Carrots were grown in control soil with standard nutrient concentrations [Sady et al. 2000], and in soil additionally fertilized with Crop Care at a rate of 0.03 kg · ha^{-1}. The chemical composition of this fertilizer was as follows: N – 10%, P – 10%, K – 20%, MgO – 4.1%, CaO – 1.4%. The experiment was performed in a randomized block design, in three replications. Plot surface area was 5.5 m^2. Early-maturing cultivars were harvested first, followed by late-maturing ones. Twenty roots were sampled from each treatment for chemical analyses.

Spice plants, i.e. marjoram, red-leaved basil and green-leaved basil, were also assayed for nitrate content. Both species were grown from seedlings produced in a greenhouse, in earthen pots filled with hotbed soil with the following organic and mineral composition: $N\text{-}NO_3$ – 200, P – 390, K – 185, Ca – 2330, Mg – 284 $mg{\cdot}dm^{-3}$, pH 6.9 in w H_2O, and salt concentration of 1.9 $mg{\cdot}dm^{-3}$. Seeds were sown at two dates. In the second half of May, seedlings were planted out in the field at a 14-day interval. Soil was prepared so as to meet the nutrient requirements of the investigated species [Martyniak-Przybyszewska 2001]. The experiment was performed in a randomized block design, in three replications. Twelve plants were grown in each plot. Plants were harvested prior to flowering.

Chili peppers and tomatoes were grown in an unheated plastic tunnel. The seeds of chili peppers and tomatoes were sown in a greenhouse, each year towards the end of March. Transplants were placed in pots with a diameter of 10 cm, filled with highmoor peat saturated with mineral nutrients, with the following chemical composition: $N\text{-}NO_3$ – 100, P – 80, K – 215, Ca – 1240, Mg – 121 mg·dm^{-3}, pH 5.9 in w H_2O, and salt concentration of 1.5 g·dm^{-3}. The seedlings of both species were planted out in an unheated plastic tunnel, in soil characterized by the following chemical composition: $N\text{-}NO_3$ – 247, P- 205, K – 400, Ca – 2162, Mg – 412 mg·dm^{-3}, pH 7.02 in w H_2O, and salt concentration of 1.6 g·dm^{-3}. Nutrient deficiency was supplemented according to the requirements of each species [Starck 1997].

The experiment with chili peppers was conducted in a randomized block design, in three replications. Two pepper cultivars were analyzed: Cayen and Cyklon. Seedlings were planted out on 18 and 19 May. Sixteen plants were grown in each plot. The fruits were harvested at the stage of physiological maturity, as they turned red. Twenty fruits were sampled from each treatment for chemical analyses.

The experiment with tomatoes grown in a plastic tunnel was carried out in a randomized block design, in three replications. The first experimental factor were the following cultivars: Baron F_1, Bawole Serce, Dukat F_1, Karmina F_1, Merkury F_1, Złoty Ożarowski, Pelikan F_1, Perkoz F_1. The second experimental factor was fertilization. Standard fertilization was applied, according to the nutrient requirements of the species [Starck 1997], followed by the application of a supplemental extended-action phosphorus-potassium fertilizer, VitroFosMak, at a rate of 0.05 kg·m^{-2}. This fertilizer contained P: K: Mg at the 10:22:12% ratio. It was mixed with soil in the tunnel, and applied before planting out the seedlings. Tomato seedlings were planted out in the first week or so of May, at the 100×50 cm spacing, 5 plants per replication. The plants were pruned for a single stem and stopped after six trusses had formed. The fruits were harvested on ripening, and 30 fruits were sampled from each treatment at the stage of full fruiting.

Plant material was dried at a temperature of 65°C [Krauze and Domska 1991]. The dried material was ground in an electric mill, and was subjected to a chemical analysis by a colorimetric method with the use of salicylic acid.

The results were validated statistically by an analysis of variance. The significance of differences between means was estimated by constructing Tukey's confidence intervals at a 5% significance level.

RESULTS AND DISCUSSION

Nitrate concentrations differed considerably among the edible parts of the analyzed vegetable species. The Regulation of the Minister of Health of 22 December 2004 [2005] sets the maximum levels for nitrates in particular groups of vegetables in Poland.

Many authors share the opinion that the nitrate content of the edible parts of vegetables is determined genetically and may vary depending on species and cultivar. It is also affected by climatic and agricultural conditions [Michalik 1996, Michalik and Ślęczak 1996, Wierzbicka et al. 2000, Wierzbicka et al. 2004, Wierzbicka and Majkowska-Gadomska 2005]. The nitrate content of the edible parts of vegetables is also influenced by temperature and precipitation (tab. 1).

Table 1. Mean temperatures and precipitation totals during the experimental period. Data provided by the Meteorological Station in Olsztyn
Tabela 1. Średnie temperatury i sumy opadów w okresie prowadzenia doświadczenia wg Stacją Meteorologicznej w Olsztynie

	Year Rok	Months – Miesiące					
		V	VI	VI	VIII	IX	means średnie
Mean temperature Średnia temperatura °C	2007	13.6	17.6	17.7	18.2	14.9	15.4
	2008	12.3	16.0	18.5	18.4	14.9	16.2
	mean of many years 1961–1990 średnia wielolecia 1961–1990	12.6	15.7	17.4	16.9	12.5	15.0
Sum of precipitations Suma opadów mm	2007	31.2	93.5	173.0	74.7	79.2	90.3
	2008	27.0	32.7	57.7	102.1	22.9	48.5
	mean of many years 1961–1990 średnia wielolecia 1961–1990	49.4	83.9	74.9	71.4	58.8	67.7

An analysis of two growing seasons, presented in this study (tab. 1), showed that mean temperature in 2007 was by 0.8°C lower than in 2008, and mean temperatures in both these years were higher than the long-term average. Mean precipitation total was higher in 2007 than in 2008. An analysis of precipitation totals in each year of the study revealed that mean precipitation total in 2007 was higher, and in 2008 lower than the long-term average.

According to Rożek [2000], variations in nitrate accumulation are in 10% dependent on the edible part of the analyzed plant. Tomato fruits (classified as berries) generally accumulate low amounts of nitrates. The NO^-_3 content of tomato fruits was significantly affected by the cultivar in both years of the study. Lower nitrate concentrations were accumulated in the fruits of cv. Bawole Serce – 178.17 mg $N\text{-}NO_3 \cdot kg$ fresh weight^{-1} (mean for 2007–2008). The cultivar x cultivation method interaction was also found to be statistically significant. In both years of the experiment, the lowest nitrate content was determined in the fruits of cv. Bawole Serce grown in soil mulched with black non-woven PP fabric, while the highest – in the fruits of cv. Złoty Ożarowski grown in mulched soil.

As shown by an analysis of successive years of the study, significantly more nitrates were accumulated in tomato fruits harvested in 2007, but the maximum permissible nitrate levels were exceeded only in the fruits of cv. Złoty Ożarowski (tab. 2), which could have been caused by lower air temperatures and high precipitation totals during the growing season. This is consistent with the findings of Rożek [2000] who demonstrated that N-NO_3 content is determined by atmospheric conditions in 25%. No significant differences in nitrate concentrations were observed between tomato fruits from the control treatment and from plants grown in soil mulched with black non-woven PP fabric.

Table 2. Nitrate content of field-grown tomato fruit
Tabela 2. Zawartość azotanów w owocach pomidora polowego

Cultivar Odmiana	Cultivation methods Metoda uprawy	Nitrates – Azotany mg N-NO_3·kg f.m^{-1} św.m^{-1}		
		2007	2008	mean średnia
Bawole Serce	control – kontrola	289.45	104.45	196.95
	mulching – mulczowanie	247.10	71.69	159.39
	mean – średnia	268.27	88.07	178.17
Złoty Ożarowski	control – kontrola	462.25	105.43	283.84
	mulching – mulczowanie	533.00	110.80	321.90
	mean – średnia	497.62	108.11	302.86
Mean – Średnia	control – kontrola	375.85	104.94	240.39
	mulching – mulczowanie	390.05	91.24	240.64
The permissible content – Dopuszczalna zawartość 400 mg				
LSD $_{0.05}$ – NIR$_{0,05}$				
Cultivar – Odmiana		41.11	16.58	n.s.
Cultivation methods – Metoda uprawy		n.s.	n.s.	n.s.
Interaction – Współdziałanie		2.20	2.71	n.s.
Years – Lata				74.39

The average nitrate content of carrot storage roots was below the maximum levels for nitrates set by the Minister of Health [2005]. In both years of the study, the investigated carrot cultivars differed significantly in respect of nitrate concentrations (tab. 3), which ranged from 49.39 mg N-NO_3·kg fresh weight^{-1} to 253.04 mg N-NO_3·kg fresh weight^{-1}, and corresponded to the values reported by Wierzbicka et al. [2004] and Murawa et al. [2008]. Among the investigated cultivars, the highest nitrate content was found in the storage roots of the early cultivar Florida F_1 in 2007 and 2008, while the lowest – in cv. Purple Haze F_1 in 2007 and in cv. Interceptor F_1 in 2008.

Supplemental fertilization had no significant effect on N-NO_3 content. A trend towards higher N-NO_3 concentrations in the storage roots of the examined carrot cultivars was observed following the application of Crop Care, both in 2007 and 2008. However, according to Rożek [2000], the nitrate content of plant yield is affected by fertilization in 30%. An analysis of the interactions between the experimental factors indicated that the storage roots of cv. Purple Haze F_1 grown in soil fertilized with Crop Care were characterized by the lowest nitrate content in 2007, whereas in 2008 the lowest nitrate concentrations were observed in the storage roots of cv. Interceptor F_1 in the control treatment. In 2007 and 2008, the highest nitrate levels were noted in the storage roots of cv. Florida F_1 grown in soil with supplemental fertilization. As shown by experimental data, nitrate concentrations varied significantly over the experimental period. The nitrate content of carrot storage roots was higher in 2008 than in 2007. The only exception was cv. Interceptor F_1 whose storage roots accumulated less nitrates in 2008, both in the control treatment and in the treatment with supplemental fertilization.

Nitrate content is an important criterion for evaluating the overall quality of herbaceous plants. Since the tested species are used as spices, their nitrate concentrations should be taken into account while determining the allowable daily intake or "safe levels" of these compounds. The interpretation of the obtained results is difficult as the maximum permissible $N\text{-}NO_3$ content has not been set for the investigated spice plants [Seidler-Łożykowska et al. 2007].

Table 3. Nitrate content of carrot storage roots
Tabela 3. Zawartość azotanów w korzeniach spichrzowych marchwi

Cultivar Odmiana	Fertilizer Nawożenie	Nitrates – Azotany mg $N\text{-}NO_3 \cdot kg$ f.m^{-1} św.m^{-1}		
		2007	2008	mean – średnia
Deep Purple Haze F_1	control – kontrola	136.88	237.27	187.07
	crop care	143.69	233.51	188.60
	mean – średnia	140.28	235.39	187.83
Florida F_1	control – kontrola	190.04	202.84	196.44
	crop care	209.09	253.04	231.06
	mean – średnia	199.52	227.94	213.73
Inetrceptor F_1	control – kontrola	109.86	49.39	79.62
	crop care	103.21	99.19	101.20
	mean – średnia	106.53	74.29	90.41
Joba	control – kontrola	107.20	100.67	103.93
	crop care	136.88	169.46	153.17
	mean – średnia	122.04	135.06	128.55
Kazan F_1	control – kontrola	93.35	131.30	112.32
	crop care	124.23	143.31	133.77
	mean – średnia	108.79	137.30	123.04
Purple Haze F_1	control – kontrola	89.92	121.15	105.53
	crop care	81.51	109.42	95.46
	mean – średnia	85.71	115.28	100.49
Mean – Średnia	control – kontrola	121.20	142.43	131.81
	crop care	133.10	165.98	149.54
The permissible content – Dopuszczalna zawartość 400 mg				
$LSD_{0.05}$ – $NIR_{0,05}$				
Cultivar – Odmiana		12.70	26.37	31.34
Fertilizer – Nawożenie		n.s.	n.s.	n.s.
Interaction – Współdziałanie		1.39	1.45	41.01
Years – Lata				33.23

The edible parts of marjoram and sweet basil are leaves, stalks and flowers. As regards marjoram, sowing date had a significant effect on nitrate content. The highest nitrate concentrations were reported for the second date of sowing (tab. 4). The nitrate

Table 4. Nitrate content of marjoram leaves
Tabela 4. Zawartość azotanów w liściach majeranku ogrodowego

Species Gatunek	Date of sowing Termin siewu	Nitrates – Azotany mg $N\text{-}NO_3 \cdot kg$ f.m $^{-1}$ św.m^{-1}		
		2007	2008	mean średnia
Marjoran Majeranek	I	765.50	858.58	812.04
	II	978.56	890.21	934.38
	mean – średnia	872.03	874.39	873.21
$LSD_{0.05}$ – $NIR_{0,05}$				
Date of sowing – Termin siewu		2.26	1.60	102.9
Years – Lata				n.s.

content of basil leaves was significantly affected by cultivar. The highest nitrate concentrations were observed in red basil leaves in 2008 (882.58 mg $N\text{-}NO_3 \cdot kg$ fresh weight^{-1}), and the lowest – in green basil leaves in 2007 (458.17 mg $N\text{-}NO_3 \cdot kg$ fresh weight^{-1}). An analysis of sowing time showed that the largest and smallest quantities of nitrates were accumulated by respectively red-leaved and green-leaved basil plants raised from the second date of sowing (tab. 5). Similar dependencies regarding nitrate accumulation in common savory were reported by Seidler-Łożykowska et al. [2007]. High nitrate levels were also observed in vegetables whose edible parts are leaves, e.g. in lettuce [Majkowska-Gadomska et al. 2005] and salad chicory [Francke et al. 2008]. As indicated by the results of these experiments, the nitrate content of the edible parts of the above species was affected by planting time.

Table 5. Nitrate content of sweet basil leaves
Tabela 5. Zawartość azotanów w liściach bazylii pospolitej

Cultivar Odmiana	Date of sowing Termin siewu	Nitrates – Azotany mg $N\text{-}NO_3 \cdot kg$ f.m $^{-1}$św.m^{-1}		
		2007	2008	mean – średnia
Red basil Bazylia czerwonolistna	I	416.00	808.80	612.40
	II	702.00	956.36	829.18
	mean – średnia	559.00	882.58	720.79
Green basil Bazylia zielonolistna	I	520.34	572.44	546.39
	II	396.00	565.26	480.63
	mean – średnia	458.17	568.85	513.51
Mean – Średnia	I	468.17	690.62	579.39
	II	549.00	760.81	654.90
$LSD_{0.05}$ – $NIR_{0,05}$				
Cultivar – Odmiana		n.s.	73.66	183.03
Date of sowing – Termin siewu		n.s.	n.s.	n.s.
Interaction – Współdziałanie		1.90	1.88	235.64
Years – Lata				127.82

Among vegetables, peppers are known to accumulate the lowest nitrate amounts in their edible parts [Rożek 2000]. As regards the effect of cultivar on the nitrate content of the fruits of *Capsicum annuum* L., larger amounts of these compounds were accumulated by cv. Cyklon, both in 2007 and 2008. The reported values did not exceed the maximum permissible concentrations. In a study conducted by Tietze et al. [2007], pepper fruits had a higher nitrate content. The differences in nitrate concentrations in chili peppers were affected by climatic conditions and by the degree of fruit ripeness at harvest in a given year (tab. 6).

Table 6. Nitrate content of chili pepper fruit
Tabela 6. Zawartość azotanów w owocach papryki ostrej

Cultivar Odmiana	Nitrates – Azotany mg $N-NO_3 \cdot kg$ f.m^{-1} św.m^{-1}		
	2007	2008	mean – średnia
Cayen	51.81	93.00	72.40
Cyklon	87.14	97.62	92.38
Mean – Średnia	69.47	95.31	82.39
The permissible content – Dopuszczalna zawartość 200 mg			
$LSD_{0.05}$ – $NIR_{0,05}$			
Cultivar – Odmiana	2.26	2.26	n.s.
Years – Lata			n.s.

Table 7. Nitrate content of tomato fruit
Tabela 7. Zawartość azotanów w owocach pomidora

Cultivar Odmiana	Fertilizer Nawożenie	Nitrates – Azotany mg $N-NO_3 \cdot kg$ św.m^{-1} f.m		
		2007	2008	mean – średnia
Baron F_1	control – kontrola	368.99	61.38	200.18
	fertilizer – nawożenie	434.67	110.22	272.94
	mean – średnia	401.83	85.80	236.31
Bawole Serce	control – kontrola	149.55	68.34	108.94
	fertilizer – nawożenie	326.42	72.20	199.31
	mean – średnia	260.48	70.27	165.37
Dukat F_1	control – kontrola	329.41	91.16	210.28
	fertilizer – nawożenie	331.45	102.33	216.89
	mean – średnia	330.43	96.74	213.58
Karmina F_1	control – kontrola	283.76	186.18	234.97
	fertilizer – nawożenie	322.26	222.10	272.18
	mean – średnia	303.00	204.13	253.56
Merkury F_1	control – kontrola	354.04	77.92	215.98
	fertilizer – nawożenie	361.08	161.34	261.21
	mean – średnia	357.56	119.63	238.59
Złoty Ożarowski	control – kontrola	420.47	197.96	309.21
	fertilizer – nawożenie	498.21	257.30	377.75
	mean – średnia	459.43	228.13	343.78
Pelikan F_1	control – kontrola	159.10	143.30	151.20
	fertilizer – nawożenie	328.01	226.94	277.47
	mean – średnia	243.55	185.12	214.33
Perkoz F_1	control – kontrola	179.81	67.18	123.49
	fertilizer – nawożenie	361.43	70.55	215.99
	mean – średnia	270.62	68.86	169.74
Mean - Średnia	control – kontrola	280.64	111.68	194.28
	fertilizer – nawożenie	370.44	152.87	261.65
The permissible content – Dopuszczalna zawartość 400 mg				
$LSD_{0.05}$ – $NIR_{0,05}$				
Cultivar – Odmiana		73.05	35.89	n.s.
Fertilizer – Nawożenie		48.15	37.77	62.35
Interaction – Współdziałanie		76.60	36.60	n.s.
Years – Lata				33.23

In the case of tomatoes grown in an unheated plastic tunnel, nitrate content was significantly affected by cultivar, fertilization and the interaction between both these factors, in both years of the study (tab. 7). Among the tested tomato cultivars, the fruits of cv. Bawole Serce were characterized by the lowest nitrate content in 2007, while the fruits of cv. Perkoz F_1 – in 2008. The effect of cultivar on nitrate concentrations in plants was also demonstrated in a previous study by Majkowska et al. [2008]. The fruits collected in 2007 and 2008 from plants grown in soil with supplemental fertilization accumulated significantly higher quantities of nitrates. In 2007, the highest nitrate concentrations were noted in tomato plants of cv. Złoty Ożarowski grown in soil with supplemental fertilization (498.21 mg $N\text{-}NO_3 \cdot kg$ fresh weight^{-1}), while the lowest – in cv. Bawole Serce from the control treatment (149 mg $N\text{-}NO_3 \cdot kg$ fresh weight^{-1}). In 2008, the highest nitrate content was recorded in tomato plants of cv. Złoty Ożarowski grown in soil with supplemental fertilization (257.30 mg $N\text{-}NO_3 \cdot kg$ fresh weight^{-1}), and the lowest – in cv. Baron from the control treatment without supplemental fertilization (61.38 mg $N\text{-}NO_3 \cdot kg$ fresh weight^{-1}).

CONCLUSIONS

1. The nitrate content of the edible parts of vegetables and spice plants depended on the species and cultivar. Among the analyzed species, the highest nitrate concentrations were noted in marjoram, while the lowest – in chili pepper fruits.

2. Among the investigated cultivars of tomatoes grown in the field and under cover, the fruits of cv. Bawole Serce were characterized by the lowest nitrate content, while the highest nitrate levels were reported for the fruits of cv. Złoty Ożarowski.

3. Supplemental fertilization contributed to a statistically significant increase in the nitrate content of tomato fruits, and to a tendency towards higher nitrate concentrations in carrot storage roots.

4. A two-week delay in sowing and planting caused a significant increase in the nitrate content of marjoram leaves, and slightly higher nitrate amounts were also accumulated in the leaves of sweet basil plants raised from the second date of sowing.

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ZAWARTOŚĆ AZOTANÓW W CZĘŚCIACH JADALNYCH WARZYW I ROŚLIN PRZYPRAWOWYCH

Streszczenie. Badania przeprowadzone w latach 2007–2008 dotyczyły zawartości azotanów w częściach jadalnych warzyw i roślin przyprawowych. Obejmowały następujące gatunki: z uprawy polowej: pomidor, marchew, bazylię pospolitą, majeranek ogrodowy, natomiast z uprawy w tunelu foliowym: pomidor i paprykę ostrą. W uprawie warzyw i roślin przyprawowych stosowano zróżnicowane metody i terminy uprawy oraz nawożenie. Spośród analizowanych odmian pomidora polowego zwiększony poziom azotanów stwierdzono w owocach odmiany Złoty Ożarowski. Podobny efekt uzyskano uprawiając 8 odmian pomidora w nieogrzewanym tunelu foliowym. Owoce odmiany Bawole Serce zawierały najmniej azotanów w odniesieniu do pozostałych odmian. Dodatkowe nawożenie zastosowane w uprawie pomidora pod osłonami istotnie sprzyjało zwiększonemu gromadzeniu azotanów. Owoce papryki ostrej z uprawy w tunelu foliowym charakteryzowały się bardzo małą ilością azotanów. W przypadku uprawy majeranku ogrodowego wykazano największą zawartość azotanów w zielu pochodzącym z drugiego terminu siewu. W korzeniach spichrzowych marchwi średnie zawartości azotanów nie przekroczyły dopuszczalnej normy. Zastosowanie w uprawie marchwi dodatkowego nawożenia wykazywało jedynie tendencje w zwiększeniu zawartości $N\text{-}NO_3$ w korzeniach marchwi.

Słowa kluczowe: azotany, pomidor, marchew, majeranek, bazylia, papryka ostra, metody uprawy, nawożenie

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