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THE LEVEL OF NITRATES, NITRITES AND OXALATES IN DIFFERENT USABLE PARTS OF DILL (*ANETHUM GRAVEOLENS* L.) DEPENDING ON PLANT HEIGHT

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Abstract. The level of nitrates, nitrites, total and soluble oxalates was determined in dill plants. Analyses of plants, which were 20-60 cm in height, and of their separate parts were carried out. In general the higher the plants, the smaller was the content of nitrates. With the assumption that the content of nitrates in whole plants is 100%, the leaf blade contained 34-49% of nitrates, the leaf petiole 127-188%, the whole leaf 68-94%, and the stem 110-135%. The level of nitrites was very low, varying within the range of 0.01-0.41 in 1 kg of dill. The higher the plants, the greater was the content of total oxalates. With the content found in whole plants taken as 100% the leaf blade contained 104-128%, the petiole 103-117%, and the whole leaf 103-125%, while the content in dill stem was 87-92%. The proportion of soluble oxalates in total oxalates was 61-71% in the leaf blade, 14-19% in the petiole, 47-51% in the intact leaf, 13-40% in the stem, and 25-49% in the whole plant. Only in the case of the stem and whole plant was this proportion greater the smaller the plant.

Key words: dill, plant height, nitrates, nitrites, oxalates

INTRODUCTION

Leafy vegetables, including those used as seasoning, highly valued chiefly on account of the biologically active compounds contained in them [Agte et al. 2000, Kidmose et al. 2001, Kmiecik et al. 2001]. However, owing to physiological factors plants of this group are, without question, among those vegetables with the highest accumulation of nitrates [Yang 1992]. This is why the regulations of the European Union permit a fairly high content of nitrates [Commission Regulation 2002]. Some leafy vegetables also contain considerable quantities of oxalates. These compounds are also classed among the more undesirable components of the human diet [Kmiecik et al. 2001, Oztekin et al. 2002].

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On account of the numerous health-promoting compounds in leafy vegetables, they are becoming increasingly popular. In addition, they are also being increasingly used as seasoning in the preparation of ready-to-eat food. Of these vegetable condiments the growing demand for green dill has been also observed. However, in spite of the fairly long season, from June to September in Polish climatic condition, when the supply of fresh dill is possible, the preservation of this vegetable is necessary to ensure its supply beyond the growing season. The basic methods of dill preservation are drying and freezing. The dill for drying should be very young or young since at this stage all parts of the plant are delicate and the short drying time means that a good quality product can be obtained. Plants at a more advanced stage of growth can be used for freezing. With both preservation methods whole plants or parts of plant can be used depending on the stage of growth.

The aim of the investigation was to determine the level of compounds undesirable in the human diet, i.e. nitrates, nitrites, total oxalates and soluble oxalates in dill plants. The investigated plants were 20, 30, 40, 50 and 60 cm in height, their separate parts, i.e. leaf blades, petioles, whole leaves, stems, and whole plants being analysed.

MATERIALS AND METHODS

The investigated material was different usable parts of dill plants, the cultivar Amat, harvested at the height of 20, 30, 40, 50 and 60 cm. Dill was cultivated in the experimental field of the Department of Raw Materials and Processing of Fruit and Vegetables, situated in the western outskirts of Krakow, on brown soil developed from loess formations with the mechanical composition of silt loam. The soil, of good horticultural quality, was characterized by an almost neutral pH value of 6.5 in H_2O, a moderate content of humus – 0.93%, and a high content of phosphorus – 70 $mg \cdot dm^{-3}$; potassium – 175 $mg \cdot dm^{-3}$; and calcium – 1460 $mg \cdot dm^{-3}$.

Dill was grown in the third year after manure fertilization with cucumbers as the preceding crop. Taking into account the soil fertility and the nutritional requirements of the species, the following doses of mineral fertilizers were applied: nitrogen before sowing – 30 kg $N \cdot ha^{-1}$ in the form of ammonium nitrate; phosphorus before sowing – 15 kg $P_2O_5 \cdot ha^{-1}$ in the form of triple super phosphate; and potassium before sowing – 30 kg $K_2O \cdot ha^{-1}$ in the form of 60% potassium chloride.

Dill was harvested when plants attained the height determined by the accepted method. This occurred after 50, 54, 59, 63, and 69 days of sowing, respectively. The selection of plant heights depended on the use of dill, i.e. at a height of 20 and 30 cm whole plants could be used especially for soups and sauces; at a height of about 40 and 50 cm whole leaves with petioles can be used for these aims. However, from plants 60 cm in height, which are bolting in this stage of development, only the leafy part or the brew from whole plants can be used in practice.

The harvest was carried out by cutting plant tops 1.5-2.0 cm above the soil. Directly after harvesting the plants are inspected, all these with yellowing leaves or single yellow leaves being discarded. The objects of the investigation were usable parts of dill: the leaf blade, petiole, whole leaf (the blade with petiole), the stem, and whole plants (the whole leaf with the stem).

Analyses were started about one hour after harvest. An average evaluated sample was about 1000 g in weight and sampled so as to be representative of the given investigated material. Chemical analyses were carried out in four replications, each in two parallel samples. The determinations concerned the level of dry matter [AOAC 1984], nitrates and nitrites using the ISO method [ISO 6635 1984], total oxalates [AOAC 1984] and water soluble oxalates [Wilson-III et al. 1982].

For the establishing of possible differences in the level of analysed indices of chemical composition between the parts of dill plants and also of differences resulting from the size of plants, an analysis of variance was carried out on the basis of the Snedecor F and Student t tests, while the least significant difference (LSD) was calculated for the level of error probability of P = 0.01 and P = 0.05 (ANOVA).

RESULTS AND DISCUSSION

The leaf blade was characterized by the greatest dry matter content significantly different from that in other parts of the plant (Table 1). With the assumption that the dry matter content in the whole plant is 100%, the leaf blade contained 129-158% depending on the plant height, and the higher the plant, the greater was its dry matter content. A similar rising tendency in this index was noted for whole leaves (109-136%), petioles (66-93%) and for stems (70-85%). Witkowska et al. [1996] state that the dry matter content varied from 8.07-14.09 mg·100g^{-1} of dill. Boelt [1990] observed a fairly small differentiation, depending on harvest time, in the content of dry matter in whole dill plants. In the present work differences between consecutive harvest times were not always significant, the difference between the extreme dates of harvest being only 15%.

Table 1. Content of dry matter in different usable parts of dill depending on height of plant, g·100 g^{-1} fresh matter*

Tabela 1. Zawartość suchej masy w częściach użytkowych kopru w zależności od wysokości rośliny, g·100 g^{-1} świeżej masy*

Height of plant Wysokość rośliny cm	Usable part of dill Część użytkowa rośliny					LSD	
	leaf blade blaszka liściowa	petiole ogonek liściowy	whole leaf cały liść	stem łodyga	whole plant cała roślina	P < 0.01	P < 0.05
20	14.45 ± 0.25	7.41 ± 0.18	12.16 ± 0.23	7.84 ± 0.20	11.20 ± 0.22	0.448	0.324
30	13.80 ± 0.23	7.18 ± 0.24	11.34 ± 0.16	6.75 ± 0.19	9.69 ± 0.08	0.398	0.288
40	14.42 ± 0.22	8.02 ± 0.25	12.06 ± 0.17	7.52 ± 0.23	9.49 ± 0.20	0.449	0.325
50	14.50 ± 0.22	8.07 ± 0.23	12.29 ± 0.17	7.65 ± 0.26	9.20 ± 0.16	0.438	0.317
60	15.42 ± 0.26	9.04 ± 0.28	13.24 ± 0.27	8.32 ± 0.17	9.75 ± 0.20	0.501	0.362
LSD P < 0.01	0.494	0.496	0.426	0.443	0.369		
LSD P < 0.05	0.357	0.359	0.308	0.320	0.267		

*Mean ± SD.

*Średnia ± odchylenie standardowe.

The determined level of nitrates did not exceed 1500 mg NO_3^- in 1 kg fresh matter of whole dill plants (Table 2). This is a relatively high content; however, leafy vegetables are classed as the group of plants containing the highest accumulations of these compounds [Yang 1992, Commission Regulation 2002]. Gębczyński et al. [2001] and Kmiecik et al. [2001] determined a higher level of nitrates in dill than that found in the present work. According to the literature data the content of nitrates in whole dill plants varies within very wide limits of 224-10721 mg NO_3^- in 1 kg fresh weight [Rostkowski et al. 1994, Siomos and Dogras 1999]. Weather conditions unfavourable for a given species and high nitrogen fertilization can contribute to an excessive accumulation of nitrates [Makus and Hettiarachchy 1999].

Table 2. Content of nitrates in different usable parts of dill depending on height of plant, mg NO_3^-·1000 g^{-1} fresh matter*
Tabela 2. Zawartość azotanów w częściach użytkowych kopru w zależności od wysokości rośliny, mg NO_3^-·1000 g^{-1} świeżej masy*

Height of plant Wysokość rośliny cm	Usable part of dill Część użytkowa rośliny					LSD	
	leaf blade blaszka liściowa	petiole ogonek liściowy	whole leaf cały liść	stem łodyga	whole plant cała roślina	P < 0.01	P < 0.05
20	712 ± 32	2 760 ± 68	1 376 ± 40	1 792 ± 72	1 468 ± 44	113.6	82.0
30	468 ± 28	2 112 ± 96	1 080 ± 40	1 812 ± 68	1 344 ± 24	119.6	86.8
40	448 ± 20	1 696 ± 68	908 ± 20	1 664 ± 92	1 336 ± 44	118.0	85.2
50	412 ± 24	1 484 ± 88	780 ± 28	1 064 ± 68	968 ± 40	116.4	84.0
60	388 ± 20	1 528 ± 64	776 ± 36	1 148 ± 44	1 040 ± 40	89.6	64.8
LSD P < 0.01	54.0	162.0	70.8	148.0	81.2		
LSD P < 0.05	38.8	117.2	51.2	107.2	58.8		

*Mean ± SD.
*Średnia ± odchylenie standardowe.

The distribution of different components in the plant changes during the growing period. Their concentration in different parts of the plant is also variable [Bano et al. 2003]. The greatest content of nitrates both in fresh (Table 2) and dry (Fig. 1) matter in all parts of dill was found in plants with the smallest height (20 cm). The taller the plants, the fewer nitrates were determined, except for the petioles, stems and the whole dill plants 60 cm in height where a 3-8% increase in the level of nitrates in comparison with dill 50 cm in height was found. The differences were only significant in whole plants and only with $P < 0.01$. In investigating four developmental stages of two spinach cultivars Watanabe et al. [1994] observed that as growth proceeded the content of nitrates in leaf blades and petioles varied. In one of three investigated cultivars of spinach Yamada et al. [2003] showed increases in the level of nitrates with the growth of plants. Lee et al. [1998] were recording increases in the content of nitrates in lettuce within 30 days of planting, although Drews et al. [1996] found gradual decreases in this content after the formation of lettuce heads.

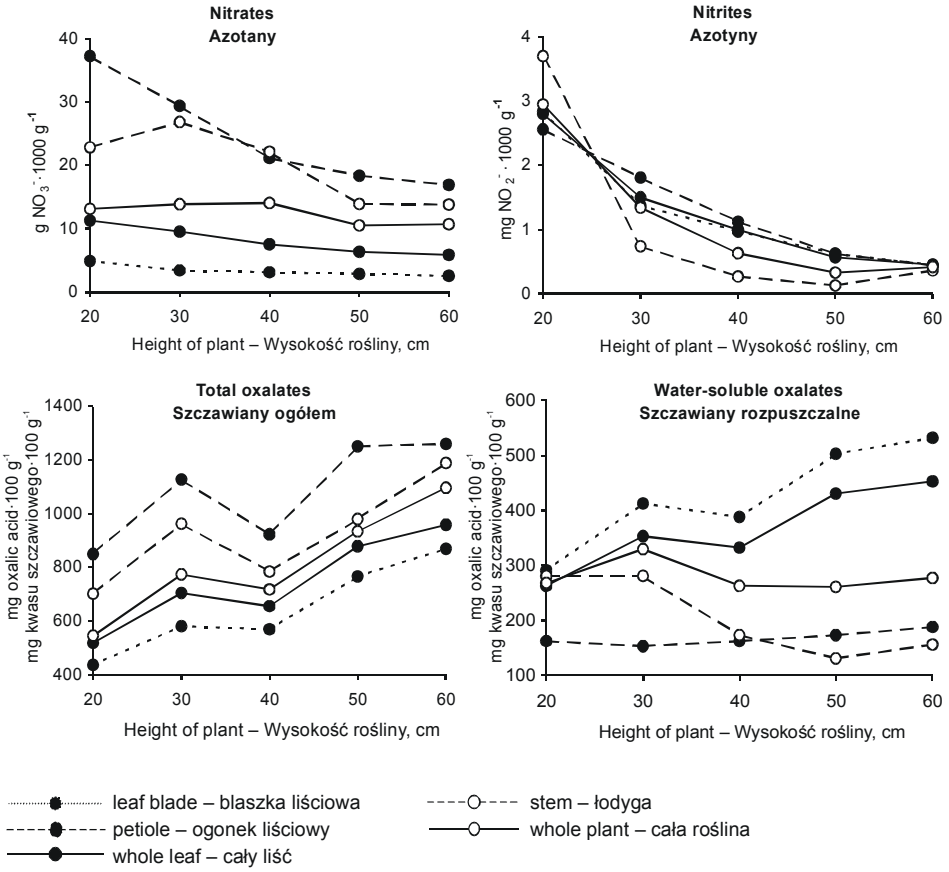

Fig. 1. Content of nitrates, nitrites and oxalates in different usable parts of dill, in dry matter
Rys. 1. Zawartość azotanów, azotynów i szczawianów w różnych częściach użytkowych kopru, w suchej masie

With the assumption that the content of nitrates in whole plants of the investigated dill – for each height separately – was 100%, the leaf blade contained 34-49% of nitrates, the petiole 127-188%, the whole leaf 68-94%, and the stem 110-135%. The differentiation in the level of nitrates depending on analysed parts of the plant was also determined for other vegetable species. A markedly greater content of nitrates was found in the petiole than in the leaf blade of common spinach [Beis et al. 2002, Oguchi et al. 1996, Biemond et al. 1996], New Zealand spinach [Jaworska 2005], leaf beet [Gębczyński 1998, Gębczyński et al. 1999], and Chinese cabbage [Ren and Lee 1997]. This can be explained by the different intensity of metabolic processes.

The level of nitrites determined in all the investigated objects varied over the range of 0.03-0.41 mg NO_2^- in 1 kg fresh matter (Table 3) and 2.56-3.70 mg NO_2^- in 1 kg dry matter (Fig. 1). This was a low value since the level of 1 mg nitrites in1 kg plant weight is regarded as a natural amount resulting from metabolic changes in the plant tissue. The highest contents of nitrites were determined in the youngest plants and in the plant part

Table 3. Content of nitrites in different usable parts of dill depending on height of plant, mg NO_2^-·1000 g^{-1} fresh matter*
Tabela 3. Zawartość azotynów w częściach użytkowych kopru w zależności od wysokości rośliny, mg NO_2^-·1000 g^{-1} świeżej masy*

Height of plant Wysokość rośliny cm	Usable part of dill Część użytkowa rośliny					LSD	
	leaf blade blaszka liściowa	petiole ogonek liściowy	whole leaf cały liść	stem łodyga	whole plant cała roślina	P < 0.01	P < 0.05
20	0.41 ± 0.06	0.19 ± 0.03	0.34 ± 0.04	0.28 ± 0.04	0.33 ± 0.04	0.090	0.065
30	0.19 ± 0.04	0.13 ± 0.03	0.17 ± 0.03	0.05 ± 0.05	0.13 ± 0.01	0.069	0.050
40	0.14 ± 0.03	0.09 ± 0.02	0.12 ± 0.02	0.02 ± 0.02	0.06 ± 0.02	0.043	0.031
50	0.09 ± 0.02	0.05 ± 0.03	0.07 ± 0.02	0.01 ± 0.02	0.03 ± 0.01	0.045	0.033
60	0.07 ± 0.03	0.04 ± 0.04	0.06 ± 0.02	0.03 ± 0.03	0.04 ± 0.02	n.s.	n.s.
LSD P < 0.01	0.078	0.061	0.059	0.065	0.049		
LSD P < 0.05	0.056	0.044	0.043	0.047	0.035		

*Mean ± SD.
*Średnia ± odchylenie standardowe.

most active in physiological changes, i.e. the leaf blade. Depending on the growing period and with plants 25 cm in height Kmiecik et al. [2001] found the content of nitrites higher by 26-69% in the leaf blade than in the whole leaf. In the present work this value was higher by 12-29%. According to other authors the content of nitrites varied from 0.00-5.36 mg in 1 kg fresh matter [Gębczyński et al. 2001, Rostkowski et al. 1994].

According to Tabekhia [1980] in 100 g dry matter of dill the content of total oxalates was 424 mg. In the present experiment whole dill plants contained 545-1097 mg of these compounds in 100 g dry matter (Fig. 1) and 61-107 mg in 100 g fresh matter (Table 4) depending on the phase of growth. The youngest whole plants and their different parts contained the smallest amount of total oxalates. The older the plants, the higher was the content of these compounds. A reverse dependence was found between the content of oxalates and nitrates. Similar tendencies in the mutual dependence between the content of oxalates and nitrates were described by Beis et al. [2002], Santamaria et al. [1999] and Watanabe et al. [1994] for 26 species of leafy vegetables with an exception of *Chenopodiacae*, where the level of nitrates and oxalates was similar in petioles and leaf blades.

The differentiation in the level of total oxalates of the various investigated parts of dill was not so distinct as in the case of nitrates. If we accept the content in whole plants as 100%, the leaf blade contained 103-129% of these compounds, the petiole 103--117%, and the whole leaf 103-126%. In the stems of dill the content of total oxalates was smaller, amounting to 87-93% in relation to that in whole plants. According to Oguchi et al. [1996] different parts of spinach did not differ in the content of oxalic acid. However, as Gębczyński [1998] and Gębczyński et al. [1999] claim, the leaf blades of leaf beet contained almost 6 times more total oxalates than the petioles. Similar

observations were reported by Savage et al. [2000] with respect to rhubarb and by Jaworska [2005] in an investigation of New Zealand spinach.

The percentage of soluble oxalates in their total content varied considerably in the analysed usable parts of dill (Table 5). However, in small measure it depended on plant

Table 4. Content of total oxalates in different usable parts of dill depending on height of plant, mg oxalic acid·100 g^{-1} fresh matter*
Tabela 4. Zawartość szczawianów ogółem w częściach użytkowych kopru w zależności od wysokości rośliny, mg kwasu szczawiowego·100 g^{-1} świeżej masy*

Height of plant Wysokość rośliny cm	Usable part of dill Część użytkowa rośliny					LSD	
	leaf blade blaszka liściowa	petiole ogonek liściowy	whole leaf cały liść	stem łodyga	whole plant cała roślina	P < 0.01	P < 0.05
20	63 ± 3	63 ± 3	63 ± 3	55 ± 4	61 ± 3	n.s.	4.5
30	80 ± 3	81 ± 3	80 ± 3	65 ± 4	75 ± 1	6.1	4.4
40	82 ± 4	74 ± 4	79 ± 2	59 ± 3	68 ± 2	6.4	4.6
50	111 ± 6	101 ± 5	108 ± 5	75 ± 3	86 ± 3	9.1	6.6
60	134 ± 6	114 ± 7	127 ± 6	99 ± 4	107 ± 4	11.6	8.4
LSD P < 0.01	9.4	9.1	8.4	7.4	6.0		
LSD P < 0.05	6.8	6.6	6.1	5.4	4.3		

*Mean ± SD.
*Średnia ± odchylenie standardowe.

Table 5. Content of water-soluble oxalates in different usable parts of dill depending on height of plant, mg oxalic acid·100 g^{-1} fresh matter*
Tabela 5. Zawartość szczawianów rozpuszczalnych w częściach użytkowych kopru w zależności od wysokości rośliny, mg kwasu szczawiowego·100 g^{-1} świeżej masy*

Height of plant Wysokość rośliny cm	Usable part of dill Część użytkowa rośliny					LSD	
	leaf blade blaszka liściowa	petiole ogonek liściowy	whole leaf cały liść	stem łodyga	whole plant cała roślina	P < 0.01	P < 0.05
20	42 ± 2	12 ± 1	32 ± 2	22 ± 2	30 ± 2	3.4	2.4
30	57 ± 4	11 ± 2	40 ± 2	19 ± 2	32 ± 2	4.8	3.4
40	56 ± 3	13 ± 1	40 ± 2	13 ±1	25 ± 1	3.9	2.8
50	73 ± 3	14 ± 2	53 ± 2	10 ± 1	24 ± 1	4.1	3.0
60	82 ± 2	17 ± 2	60 ± 2	13 ± 1	27 ± 1	3.8	2.7
LSD P < 0.01	5.9	3.3	4.4	2.9	2.8		
LSD P < 0.05	4.2	2.3	3.2	2.0	2.0		

*Mean ± SD.
*Średnia ± odchylenie standardowe.

height, except for the stem and whole plant. In the leaf blade the proportion of soluble oxalates in total oxalates varied from 62-70%, in the petiole from 15-18%, and in the whole leaf from 48-50%, in the stem and whole plant this proportion was gradually decreasing. In the smallest plants it was 40% and 49% respectively, attaining 13% and 25% respectively in the largest. Makus and Hettiarachchy [1999] report that in leafy vegetables soluble oxalates constitute 21-27% of total oxalates. A much wider range of 14-55% of soluble oxalates in their total content was given by Carlsson [1983] for 12 species of leafy vegetables.

CONCLUSIONS

In general the higher the plants, the smaller was the content of nitrates. The lowest content of those components was in the leaf blades, and the higher was in the petioles and stems. The level of nitrites was very low. The higher the plants, the greater was the content of total oxalates. The lowest concentration of total oxalates was in stems and that in the blades, petioles and whole leaves was similar. The highest proportion of soluble oxalates in total oxalates was in the leaf blades, and the lowest was in the petioles.

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POZIOM AZOTANÓW, AZOTYNÓW I SZCZAWIANÓW W RÓŻNYCH CZĘŚCIACH UŻYTKOWYCH KOPRU W ZALEŻNOŚCI OD WYSOKOŚCI ROŚLINY

Streszczenie. Celem przedstawionych badań było określenie poziomu azotanów, azotynów, szczawianów ogółem i szczawianów rozpuszczalnych w roślinach kopru. Analizom poddano rośliny o wysokości 20, 30, 40, 50 i 60 cm analizując poszczególne części rośliny, to znaczy część liściową, ogonek liściowy, całe liście (część liściowa wraz z ogonkiem liściowym), łodygę i całą roślinę (całe liście wraz z łodygami). Im rośliny były wyższe, tym azotanów z reguły było mniej. Przy założeniu, że zawartość azotanów w całych roślinach wynosi 100%, blaszka liściowa zawierała 34-49% azotanów, ogonek liściowy – 127-188%, cały liść – 68-94%, a łodyga – 110-135%. Poziom azotynów był bardzo niski i zawierał się w przedziale 0,01-0,41 w 1 kg kopru. Im rośliny kopru były wyższe, tym było w nich więcej szczawianów ogółem. Przyjmując za 100% ilość stwierdzoną w całych roślinach, blaszka liściowa miała tych związków 104-128%, ogonek liściowy – 103--117%, cały liść także więcej – 103-125%, zaś łodyga kopru – 87-92%. Udział szczawianów rozpuszczalnych w szczawianach ogółem wynosił: w blaszce liściowej – 61-71%, w ogonku liściowym – 14-19%, w całym liściu – 47-51%, w łodydze – 13-40% i w całej roślinie – 25-49%. Przy czym tylko w łodydze i całej roślinie udział ten był tym większy, im mniejsza była roślina.

Słowa kluczowe: koper, wysokość rośliny, azotany, azotyny, szczawiany

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