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ASSESSMENT OF QUALITY ATTRIBUTES OF ENDIVE (*Cichorium endivia* L.) DEPENDING ON A CULTIVAR AND GROWING CONDITIONS

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Abstract. Endive plants were hydroponically grown in greenhouse control conditions. The aim of this investigation was to assess the biological quality of endive cultivated in three different growing media. Organic media: coconut fiber and wood fiber, were compared to rockwool, commonly used as a standard horticultural medium in greenhouse vegetable production. Three *crispum* leaf endive cultivars: 'Galanti', 'Perceval' and 'Barundi' and one *latifolium* leaf cultivar (escarole chicory): 'Kethel' were examined during the spring time. At about 10 days before harvest the plants were covered with low tunnel made from double-sided black and white foil to bleach the leaves and at 5–7 days before the end of the experiment nutrient solution was replaced by water to reduce the nitrate concentration in the leaves of endive. The content of dry matter, ascorbic acid, total soluble solids (TSS), total sugars (TS), phenolic acids and nitrates (NO_3), P, K and Ca was determined in leaves of both bleached and not bleached plants. Also the antioxidant activity was measured by two assays DPPH and FRAP. The effect of cultivation substrate, cultivar, and bleaching treatment on the quality of endive appeared diversed. The unbleached endive showed a higher content of dry mass, higher concentrations of sugars, TSS, potassium, and calcium than the bleached plants. The bleached plants had significantly lower fresh mass of plants (by 33% in average), but in turn were characterized by higher concentrations of phosphorus and polyphenolic acids. Plants cultivated on wood fiber contained the smallest amount of nitrates, comparing to plants grown either on rockwool or coconut fiber. None of the investigated plants contained more nitrates than the acceptable level of nitrates for lettuce grown under cover. The antioxidant activity of endive plants measured by FRAP method was higher in not bleached endive plants than in the bleached ones. The antioxidant impact of endive plants expressed as DPPH was not reduced in response to bleaching. The highest antioxidant activity was observed in plants of 'Kethel'.

Key words: coconut fiber, wood fiber, rockwool, bleaching, antioxidant activity, nitrates

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INTRODUCTION

Endive (*Cichorium endivia* L.) also called Belgian endive or witloof is characterized by a high content of nutrients. Endive as well as lettuce, belonging to the Asteraceae family, are the most popular vegetables in salads which are consumed in increasing amounts due to their healthy properties [DuPont et al. 2000]. Sesquiterpene lactones present in the endive's leaves responsible for the bitter taste, promote appetite and stimulate the secretion of bile [Peters and Van Amerongen 1998, Kisiel and Michalska 2008]. For many consumers the bitter trait is undesirable thus in order to enhance the taste, endive plants are subjected to a bleaching treatment or self- bleaching varieties are cultivated. Bleached leaves are crisp, of yellow-green colour and have a delicate taste with a middle absent of bitterness. Endive is also a source of ascorbic acid, carotenoids and polyphenols, component that are valued for their antioxidant properties [Aherne and Brien 2002, Murillo et al. 2010]. Epidemiological studies have shown that diet rich in vegetables and fruits significantly reduces the incidence of chronic diseases such as cancer and cardiovascular disease [Bazzaro et al. 2002, Riboli and Norat 2003]. The protective effects of vegetables and fruit may be attributed by their antioxidant content [Naczk and Shahidi 2006, Lako et al. 2007]. Secondary metabolites play a major role in the adaptation of plants to the environment and in overcoming stress conditions. The concentrations of various secondary plant products are strongly dependent on the growing conditions and have impact on the metabolic pathways responsible for the accumulation of the related natural products [Ramakrishna and Ravishankar 2011]. An increasing number of evidence suggests that both genotype and growing conditions may alter the antioxidant composition and properties in a selected agricultural crop [Lee and Kader 2000, Liu et al. 2007]. According to Llorach and coworkers [2008] 'Lollo Rosso' lettuce presents a higher level of antioxidant activity as compared to 'Iceberg', however it is 'Escarole' that has the highest reported levels (775.3 $mg \cdot 100\ g^{-1}$ of fresh mass, DPPH). Fan and Sokorai [2005] reported values of FRAP for endive of 6612 $\mu mol \cdot kg^{-1}$, and lettuce of 6750 $\mu mol \cdot kg^{-1}$. Oh and coworkers [2009], among others, obtained a significant increase in antioxidant capacity of lettuce by cultivating the plant under a moderate environmental stress. In 2001, Wang and Zheng reported the effects of growth temperature on antioxidant capacity in strawberries. Furthermore, the higher the intensity of light during the growing season, the greater is vitamin C content in plant tissues. Moreover, nitrogen fertilizers at high rates tend to decrease the vitamin C content in many fruits and vegetables and vitamin C content of many crops can be increased with less frequent irrigation [Lee and Kader 2000].

High biological value of the species is also achieved by a low content of compounds which are harmful to health. An excessive content of nitrates in vegetables is an undesirable because nitrites and nitro-compounds appear to be harmful to consumer health [Blom-Zandstra 2008]. Although nitrate is apparently non-toxic below maximum residue levels, it may be endogenously transformed to nitrite which can react with amines and amides to produce N-nitroso compounds [Yordanov et al. 2001, Santamaria 2006]. Nitrate concentrations in vegetables depend on the biological properties of the plant culture and inter alia on the irradiance, type of soil, temperature, humidity, vegetation period, harvesting time, and source of nitrogen [Tamme et al. 2006]. Nitrogen fertilisation and light intensity have been identified as the major factors that influence nitrate content in vegetables [Gruda 2005, Santamaria 2006]. Generally, nitrate-accumulating vegetables belong to the family Asteraceae. Obtaining vegetables with high biological value includes many factors, such as cultivar, microclimatic conditions, soil and rational fertilization [Amr and Hadidi 2001, Wang and Zheng 2001, Liu et al. 2007].

During the last years, an increase of endive cultivation in Poland and other European countries is observed. In greenhouses, endive is cultivated either in a traditional way or by using a soilless systems in form of horticultural or hydroponic substrates. Although endive is cultivated mainly in spring and autumn period, it is suitable for growing all year round. In hydroponic cultures are used both organic and mineral substrates which characterised by diverse properties what probably may affect the accumulation of minerals components. The content and concentration of minerals are crucial for the plant growth and development parameters as well as its quality. A periodical elevation of the concentration in nutrient solution is one of the possible methods used to enhance the yield quality in hydroponics [Tzortzakis 2010].

The aim of this study was to evaluate the effect of a growing medium, endive's cultivar and bleaching treatment on the plant's quality and antioxidant activity during spring time cultivation.

MATERIALS AND METHODS

The experiments were carried out in a greenhouse with controlled microclimate in the years 2009 and 2010 at Warsaw University of Life Sciences. Four endive cultivars from Rijk Zwaan, including: three *crispum* leaf cultivars: 'Galanti', 'Perceval' and 'Barundi' and one *latifolium* leaf cultivar (escarole chicory): 'Kethel' were obtained. The plants were cultivated in the spring cycle on organic media such as coconut fiber slabs (manufacturer: Ceres Intern.), wood fiber slabs (Steico S.A.) and rockwool slabs (Grodan BV, Master type), commonly used as the standard growing medium for tomato. Slabs dimensions in all cases were 100 × 15 × 7.5 cm (length × width × height). Ten days before harvest half of the plants were subjected to bleaching by being covered with low tunnel which was made from double-sided black and white foil to bleach the leaves. The experiment was established in random design, with three replications and 15 plants in each. The four week old endive seedlings, growing in plastic pots (5 cm high and 4 cm diameter) filled with peat, were transplanted on the growing slabs, 5 plants/slab, on 23 of March 2010 and on 24 of March 2011. The plants were ready for harvest respectively on 5 of May 2010 and on 11 of May 2011. Fertigation for plants contained 140 $mg \cdot dm^{-3}$ of nitrogen in the form of ions NO_3^-. The nutrient solution in 1 dm^3 contained the following amounts of elements in mg: P – 50, K – 300, Mg – 40, Ca – 200, Fe – 2, Mn – 0.6, B – 0.3, Cu – 0.15, Zn – 0.3 i Mo – 0.05. The nutrient media were applied to plants via 3 individual droppers for each growing slab. For the whole cultivation period pH of the nutrient solution in the growing slabs was kept at the level of 6.7 and EC 2.8 $mS \cdot cm^{-1}$. The last week grow to harvest the plants were only watered (no nutrient solutions were applied). For chemical analysis, maturity plants (ready for harvest) were selected randomly from each replication. The plants were examined for dry matter content and chemical quality attributes. From each of the plants selected a representative sample (comprising fragments of leaves of different age from youngest to eldest) was collected. Leaf samples were then cut into small fragments and mixed together. Dry matter was determined by drying leaf samples in an oven at 105ºC. The content of ascorbic acid (AA) was determined using the Tillmans' method according to Polish Standards PN-90/A-75101/11 [Drzazga 1974], the content of total soluble solids (TSS) using digital refractometer and total sugars (TS) were analyzed according to the Luff-Schoorl method. Concentration of nitrates (V) was determined in fresh matter (spectrophotometrically method by Fiastar 5000 analyzer) in 2% acetic acid extract according to Nowosielski [1988]. In the same extract the P content via the colorimetric test and the K and Ca contents via the flame method were determined.

The total content of phenolic acids (TCPA) in raw leaves of endive plants was determined spectrophotometrically according to the Polish Pharmacopoeia VI [2002]. The raw material was extracted with water. Absorbance of the solution consisting of this extract, Arnov reagent, 1 n HCL, and 1 n NaOH was measured at 490 nm. The content of polyphenolic acids was calculated as caffeic acid equivalents.

The antioxidant activity was determined by using two methods DPPH and FRAP. Extracts preparation: 5 g of fresh material was extracted with 100 ml of methanol using Büchi B-811 extraction system (modified Soxhlet extractor). Extracts were evaporated, residues were dissolved in 10 ml of methanol.

DPPH scavenging activity of examined extracts (prepared as it is described above) was carried out according to Yen and Chen [1995] assay. Results were calculated according to relationship proposed by Rossi et al. [2003]. Absorbance was measured on the UV-Vis Shimadzu 1700 PharmaSpec spectrophotometer. The total antioxidant capacity of extracts was determined against a green tea.

FRAP was examined according to Benzie and Strain [1996, 1999]. Change in absorbance caused by reduction of Fe^{3+} to Fe^{2+} in examined sample using UV-Vis Shimadzu 1700 PharmaSpec spectrophotometer was measured. The total antioxidant capacity of extracts was determined against a standard of known FRAP value, ferrous sulphate.

Statistical analysis was performed using three-way analysis of variance (ANOVA). Results for individual years were regarded as repetitive values in a statistical test. The smallest significant difference was found using the Tukey's test at the significance level of $p = 0.05$.

RESULTS AND DISCUSSION

The bleaching treatment fundamentally changed the composition of endive leaves. The not bleached plants showed a higher fresh mass of plants (by 33% in average), a higher content of dry mass (by 27% in average) and a higher content of sugars (by 80% in average) as compared to the bleached plants (tab. 1). The unbleached plants were also characterized by an increased content of TSS (20%), potassium (15%) and calcium (over 30%) and, in the case of cultivation on substrates as rockwool or wood fiber, a higher content of ascorbic acid. This would be consistent with the results of Lee and Kader [2000] who reported that with better light conditions during the growing, plants contain more vitamin C. Only the bleached endive plants grown on coconut fiber had higher contents of ascorbic acid when compared to the unbleached plants. On the other hand, each group of the bleached endive plants showed a higher content of phosphorus and polyphenolic acids comparing to the unbleached plants, irrespective of the type of substrates studied (tab. 1). The different amounts of the compounds tested in response to bleaching mainly resulted from specific pathways of metabolic processes that are influenced by light.

The endive was obtained the highest mass of plants, in spring growing cycle, where was cultivated on coconut fiber, then on rockwool and the lowest one in the case of wood fibre. Furthermore yielding of endive was depending on the cultivar.

All plants were watered at the end of the grown phase, however the significant effect of reducing the level of nitrates was noted for the endive plants cultivated on wood fibre and rockwool. Whereas, none of investigated plants contained higher amount of nitrates as permissible level of nitrates which for lettuce grown under cover and harvested from 1 of April to 30 of August be 3500 mg NO_3 per 1 kg of fresh mass of lettuce. In the case of cultivars, the lowest concentration of nitrates was found in leaves of 'Perceval'. This cultivar was well as characterized by smaller contents of potassium and phosphorus comparing to any other cultivar (tab. 1). Adamczewska-Sowińska and Miłowana Uklańska [2010] and Koudela and Petříkova [2007] suggested that endive cultivars of escariole group characterize higher tendencies to nitrogen accumulation in the form of nitrates in comparison to endive cultivars belonging to curly – leaved group. The opposite results obtained Rekowska and Jurga-Szlempo [2011]. The results of Reinink et al. [1994] indicated also that there may be some possibilities to reduce the nitrate content of endive by cultivar choice or breeding. However, the chances of obtaining a substantial reduction of the nitrate content of endive seemed less than in some other crops, such as lettuce.

The plants grown on coconut or wood fiber and bleached all had similar content of nitrates which was slightly higher comparing to the group of unbleached plants. This might be attributed to specific properties of particular substrates. Rockwool for instance is an inert growing media that rapid loses nutrients as they are washed away. Whereas wood fiber is easily mineralization. According to Adamczewska-Sowińska and Miłowana Uklańska [2010], the method of fertilization, as well as nitrogen doses considerably affected nitrates accumulation in endive.

The unbleached endive plants contained the highest concentration of ascorbic acid when cultivated on rockwool, however concentrations of sugars and phosphorus were higher when wood fiber was used as a cultivation medium. The plants grown on this medium showed the lowest concentration of nitrates and higher concentrations of sugars and TSS comparing to rockwool or coconut fiber. Endive plants cultivated on coconut fiber were characterized by a high concentration of calcium and particularly high concentration of potassium. This was also the group of plants where after bleaching had the highest content of dry mass, and concentrations of ascorbic acid, potassium, calcium and nitrates (tab. 1). The nitrate levels of the cultivars studied by Reinink et al. [1994] showed also interactions with growth medium. Lucarini et al. [2012] found on nitrate levels in both lettuce and red radicchio suggested that both genetic factors and cultivation systems strongly affect the nitrate accumulation capacity. Otherwise, light has

Table 1. Effect of bleaching of plants and kind of growing medium and cultivar on the selected quality attributes of endive plants (mean values for two years)

Treatment	Growing medium	Cultivar	Fresh mass of plant (g)	Dry matter (%)	AA (mg·100 g^{-1} fr. w.)	TS (g·100 g^{-1} fr. w.)	TSS	TCPA	NO_3 (mg·100 g^{-1} fr.w.)	P	K	Ca
Not bleached	rockwool	Galanti	294.5	7.5	32.9	0.46	2.5	0.033	213.4	13.9	416.6	42.9
		Perceval	290.8	5.3	20.6	0.46	2.3	0.028	159.6	9.3	361.2	46.7
		Kethel	378.8	5.8	29.7	0.41	2.1	0.037	208.7	12.9	383.5	39.3
		Barundi	228.8	6.5	28.6	0.55	2.4	0.031	194.7	15.3	393.5	23.3
		mean	298.2	6.3	28.0	0.47	2.3	0.032	194.1	12.9	388.7	38.1
	coconut fiber	Galanti	311.2	6.0	21.9	0.50	2.7	0.034	201.9	14.9	440.5	34.5
		Perceval	339.2	5.4	24.3	0.67	2.6	0.031	182.3	10.0	401.2	50.6
		Kethel	355.5	5.4	20.4	0.50	2.0	0.031	262.2	12.8	428.0	42.7
		Barundi	271.8	5.7	22.6	0.58	2.3	0.029	229.2	14.3	469.7	37.6
		mean	319.4	5.6	22.3	0.56	2.4	0.031	218.9	13.0	434.9	41.4
	wood fiber	Galanti	252.2	6.0	22.4	0.74	2.7	0.034	83.5	14.3	387.0	34.9
		Perceval	241.5	5.7	22.0	0.62	2.5	0.031	67.3	11.7	325.8	39.4
		Kethel	346.8	6.2	21.4	0.67	2.7	0.043	112.6	15.7	380.1	27.9
		Barundi	218.5	6.2	21.4	0.77	2.8	0.030	88.5	16.7	395.9	32.7
		mean	264.8	6.0	21.8	0.70	2.7	0.035	88.0	14.6	372.2	33.7
	mean for treatment		294.1	6.0	24.0	0.58	2.5	0.033	167.0	13.5	398.6	37.7
Bleached	rockwool	Galanti	168.6	4.7	15.3	0.07	2.3	0.033	141.2	43.6	337.5	22.7
		Perceval	185.0	4.7	15.13	0.02	1.6	0.035	156.7	37.8	294,8	20.7
		Kethel	214.8	3.4	15.6	0.05	2.0	0.035	120.5	39.0	270.9	18.3
		Barundi	160.8	4.3	16.4	0.02	1.9	0.033	146.6	33.0	319.0	19.8
		mean	182.3	4.3	15.6	0.04	2.0	0.034	141.3	38.4	305.6	20.4
	coconut fiber	Galanti	198.2	4.3	29.6	0.12	2.1	0.033	243.1	22.8	396.8	26.4
		Perceval	226.3	4.6	33.3	0.17	1.9	0.030	135.7	13.5	323.0	38.0
		Kethel	272.2	4.6	26.5	0.02	1.9	0.033	256.5	30.8	356.8	24.9
		Barundi	214.2	5.0	26.8	0.10	1.8	0.040	269.2	20.6	422.9	23.0
		mean	227.7	4.6	29.1	0.10	1.9	0.034	226.1	21.9	374.9	28.1
	wood fiber	Galanti	177.5	4.5	16.1	0.02	2.2	0.034	113.3	34.0	312.5	18.1
		Perceval	194.7	4.7	17.5	0.05	1.9	0.037	104.2	21.5	391.0	44.1
		Kethel	241.0	4.0	15.1	0.17	1.8	0.038	86.7	21.6	253.4	24.4
		Barundi	128.3	4.4	23.9	0.02	2.1	0.031	218.4	26.9	361.5	16.7
		mean	185.4	4.4	18.2	0.07	2.0	0.035	130.7	26.0	329.6	25.8
	mean for treatment		198.5	4.4	20.9	0.07	2.0	0.034	166.0	28.8	336.7	24.8

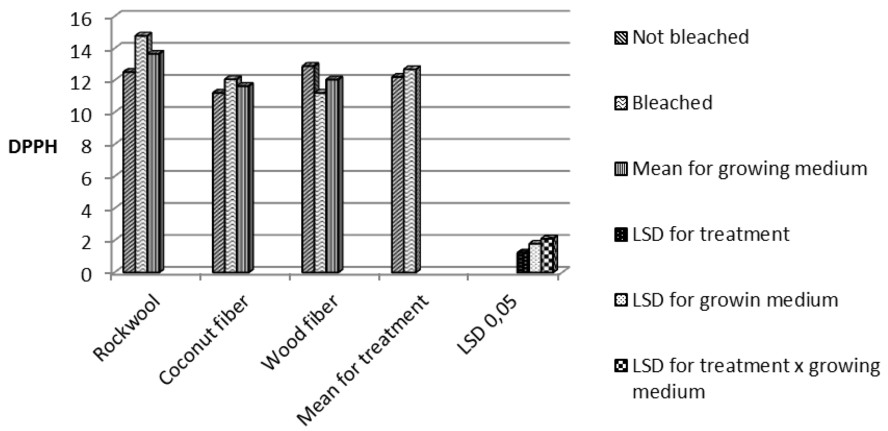
Mean for growing medium	rockwool	240.3	5.3	21.8	0.26	2.2	0.033	167.7	25.7	347.2	29.3
	coconut fiber	273.6	5.1	25.7	0.33	2.2	0.033	222.5	17.5	404.9	34.8
	wood fiber	225.1	5.2	20.0	0.39	2.4	0.035	109.4	20.3	350.9	29.8
Mean for cultivars	Galanti	233.7	5.5	23.0	0.32	2.4	0.034	166.1	23.9	381.8	29.9
	Perceval	246.3	5.1	22.1	0.33	2.1	0.032	134.3	17.3	349.5	39.9
	Kethel	301.5	4.9	21.5	0.30	2.1	0.036	174.5	22.1	345.5	29.6
	Barundi	203.7	5.4	23.3	0.34	2.2	0.032	191.1	21.1	393.8	25.5
$LSD_{0.05}$ for:	treatment (A)	7.40	0.24	1.95	0.09	0.11	0.001	ns	3.81	19.45	2.58
	growing medium (B)	10.83	ns*	2.87	ns	0.16	ns	29.57	5.61	28.65	3.80
	variety (C)	13.71	0.45	ns	ns	0.20	0.003	37.61	ns	36.45	4.84
Interaction:	A × B	12.82	0.41	3.37	ns	ns	ns	34.76	6.6	ns	4.47
	B × C	21.66	0.70	5.74	ns	ns	0.005	ns	ns	ns	7.61
	A × B × C	25.63	ns	ns	ns	ns	ns	ns	ns	ns	8.94

* ns means are not statistically different at the $p < 0.05$ level

a crucial role in regulation of NO_3 accumulation, because it is involved in photosynthesis as well as in uptake, translocation and reduction of NO_3 [Merlo et al. 1994].

In the endive plants cultivated on rockwool and bleached, the antioxidant activity expressed as free radical scavenging activity (DPPH), appeared higher than in the unbleached plants (fig. 1a). In plants cultivated on coconut fiber and wood fiber DPPH values were comparable irrespective of the plants were bleached. The antioxidant activity in not bleached endive plants measured by FRAP was higher on average by 40% than the bleached plants, irrespective of the kind of cultivation substrate used (fig. 1b).

a)



b)

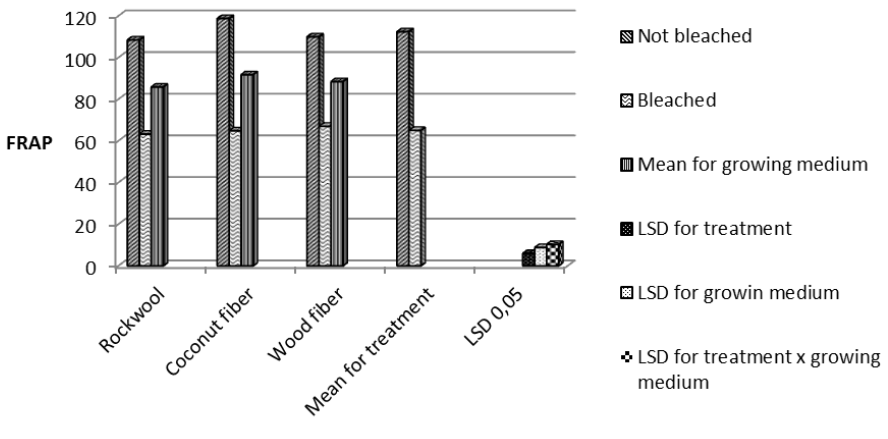
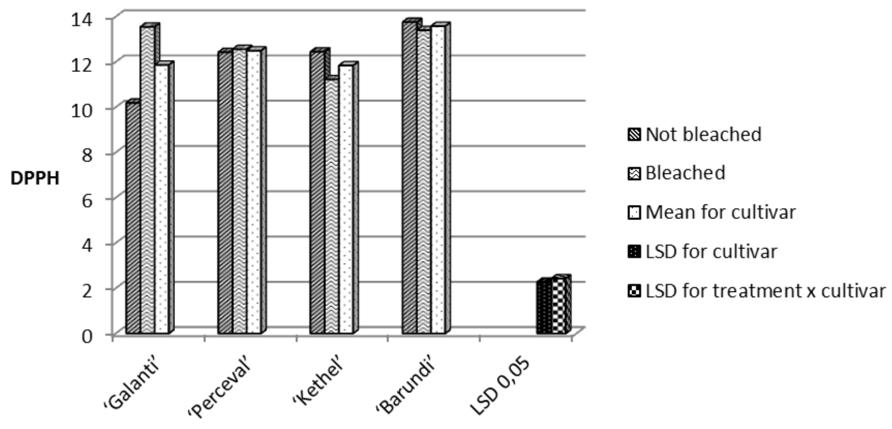


Fig. 1a, b. Effect of growing medium and bleaching of plants on the antioxidant activity of endive determined by DPPH (%) and FRAP (μmol $Fe^{3+} \cdot g^{-1}$ fr. w) a)



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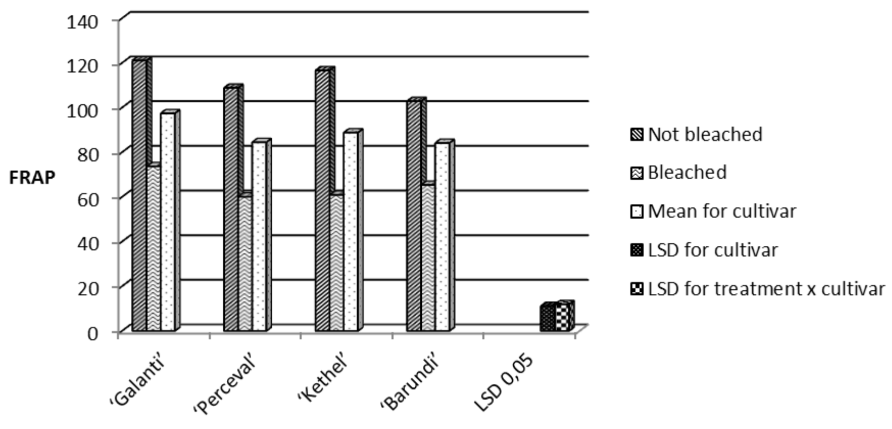

Figure 2a, b. Effect of cultivar and bleaching of plants on the antioxidant activity of endive determined by DPPH (%) and FRAP (μmol $Fe^{3+} \cdot g^{-1}$ fr.w)

Lower concentrations of the majority of the compounds studied attributed to the lower FRAP values. DPPH values increased in bleached plants are grown on rockwool and to a lesser extent, in plants from coconut fiber cultivation. One of the plant's compounds potentially affecting free radical scavenging activity is polyphenolic acids, there were observed in an elevated concentration in the bleached plants. The plants grown on coconut fiber showed a high concentration of ascorbic acid, higher than unbleached plants grown on the same cultivation medium. According to Li and Kubota [2009], it is both the lettuce cultivar and cultivation conditions that determine the content of phenolic compounds and the plant's antioxidant capacity. The results revealed only the presence of some fraction of reactive components within the sample, which was greater the faster the reaction. The FRAP method represents the majority of components, while the DPPH method only a part of the most reactive components [Barton et al. 2005]. Different endive cultivars varied in terms of the content of specific compounds and their antioxidant activity (tab. 1). Leaves of 'Galanti' and 'Barundi' contained more dry mass comparing to 'Perceval' and 'Kethel'. Cultivars 'Kethel' and 'Galanti' showed the highest concentrations of ascorbic acid and polyphenolic acids, 25.3 and 25.7 $mg \cdot 100\ g^{-1}$ of fresh mass, and 0.037 and 0.034%. respectively. According to Isabelle et al. [2010] the average content of ascorbic acid was 351.6 $\mu g \cdot g^{-1}$ fresh mass in endive. Llorach and coworkers [2008] reported the content of ascorbic acid to be: iceberg lettuce at 4.2 10 $mg \cdot 100\ g^{-1}$, lollo rosso – 11.7 $mg \cdot 100\ g^{-1}$ and escarole at 10.2 $mg \cdot 100\ g^{-1}$ of fresh mass whereas Salazar at al. [2006] report that the level of ascorbic acid reached just 8 $mg \cdot 100\ g^{-1}$ of fresh mass for lettuce and 10 $mg \cdot 100\ g^{-1}$ of fresh mass for endive.

The antioxidant DPPH activity increased in the bleached plants in relation to the unbleached ones and the trend was observed for all of the cultivars studied except for 'Kethel', where the bleaching treatment resulted in the reduction of the antioxidant activity (fig. 2a). Unlike in other cultivars, in 'Kethel' plants the bleaching treatment caused the decrease of the content of polyphenolic acids. This may support the suggestion that the DPPH can be correlated with the plant's contents of polyphenolic acids. Żukiewicz-Sobczak et al. [2009] found such a correlation between phenolic acids and the capacity to scavenge free radical DPPH while analyzing fruit beverages.

Phenolic substances are a category of phytonutrients that exert strong antioxidant properties [Ho 1992]. There is a wide degree of variation between different phenolic compounds in their effectiveness as antioxidant [Robards et al. 1999]. Oh et al. [2009] reports, that the concentration of flavonoids and phenolic acids in lettuce increases with higher photosynthetic photon flux density. However, studies on the effect of shading (i.e. low PPFD) are scarce. There are indications that the phenolic status of plants is quite dynamic and reacts to changes in radiation and availability of carbohydrates, respectively, within several days [Tsormpatsidis et al. 2010]. Also, Becker et al. [2013] no significant influence of radiation intensity on the concentration of phenolic acids or anthocyanin glycosides in red lettuce observed. Their results suggest that saving energy in early growth stages is feasible without losses in yield or health promoting phenolic substances.

The antioxidant activity measured by FRAP decreased rapidly in response to the bleaching treatment in all of the tested endive cultivars (fig. 2b). The obtained results agree with earlier reports showing that both the species and the cultivar have genetically defined antioxidant potential, that can be modified by environmental factors [Kalt et al. 2001]. Amin et al. [2004] observed that each type of vegetable had a different antioxidant activity, as a result of different antioxidant components.

CONCLUSIONS

1. The bleaching treatment on endive significantly decreased fresh mass of plants and affected their quality attributes.

2. The unbleached endive showed a higher content of dry mass, higher concentrations of sugars, TSS, potassium, and calcium than the bleached plants, which in turn were characterized by higher concentrations of phosphorus and polyphenolic acids.

3. Plants cultivated on wood fiber contained the smallest amount of nitrates, but the highest amount of sugars and TSS, comparing to plants grown either on rockwool or coconut fiber.

4. The endive harvested from substrates as rockwool or coconut fiber had an elevated level of calcium but was particularly rich in potassium.

5. The antioxidant activity of endive plants measured by FRAP method was higher in not bleached endive plants than in the bleached ones. The antioxidant impact of endive plants expressed as DPPH was not reduced in response to bleaching.

6. The highest antioxidant activity was observed in plants of 'Kethel' cultivar but the lowest concentration of nitrates was found in leaves of 'Perceval'.

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WPŁYW ODMIANY I WARUNKÓW UPRAWY NA CECHY JAKOŚCIOWE ENDYWII (*Cichorum endivia* L.)

Streszczenie. Rośliny endywii uprawiano hydroponicznie w kontrolowanych warunkach szklarniowych. Celem badań była ocena jakości biologicznej endywii uprawianej na trzech różnych podłożach. Porównywano podłoża organiczne – włókno kokosowe i drzewne – z wełną mineralną, podłożem powszechnie stosowanym w uprawie warzyw pod osłonami. Uprawiano, w terminie wiosennym, trzy odmiany endywii o kędzierzawych liściach: Galanti, Perceval i Barundi oraz jedną o liściach całobrzegich (escariola) – Kethel. Na około 10 dni przed zbiorem rośliny zastały przykryte dwustronną czarno-białą folią w celu bielenia liści, a na 5–7 dni przed końcem doświadczenia pożywkę do fertygacji zastąpiono wodą, aby zmniejszyć stężenie azotanów w liściach. Po zbiorze w roślinach bielonych i niebielonych badano zawartość suchej masy, kwasu askorbinowego, składników rozpuszczalnych w soku komórkowym (SRSK) oraz cukrów ogółem, kwasów fenolowych, azotanów (NO_3), P, K i Ca. Aktywność antyoksydacyjną endywii mierzono metodami DPPH i FRAP. Stwierdzono zróżnicowany wpływ podłoża, odmiany i zabiegu bielenia na jakość endywii. Niebielona endywia miała większą zawartość suchej masy, cukrów, składników rozpuszczalnych w soku komórkowym (SRSK), potasu i wapnia niż rośliny po bieleniu. Rośliny po bieleniu osiągały niższą świeżą masę (średnio o 33%), ale z kolei zawierały więcej fosforu i kwasów polifenolowych. Rośliny uprawiane na podłożu z włókna drzewnego zawierały najmniejszą ilość azotanów w porównaniu z roślinami uprawianymi w matach z wełny mineralnej czy włókna kokosowego. Żadne z badanych roślin nie zawierały więcej azotanów niż wynosi dopuszczalny poziom azotanów w liściach sałaty z uprawy pod osłonami. Silniejsze właściwości antyoksydacyjne, mierzone metodą FRAP, stwierdzono u roślin endywii niepoddanych bieleniu niż bielonych. W przypadku metody DPPH nie stwierdzono istotnego zmniejszenia przeciwutleniających właściwości roślin endywii w wyniku zabiegu bielenia. Największą aktywność antyoksydacyjną stwierdzono u roślin odmiany 'Kethel'.

Słowa kluczowe: włókno kokosowe, włókno drzewne, wełna mineralna, wybielanie, aktywność antyoksydacyjna, azotany

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