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Assessment of quality attributes of endive (*Cichorum endivia* L.) depending on cultivar and growing conditions

INTRODUCTION

Endive (Cichorium endivia L.) also called Belgian endive or witloof is characterized by a high content of nutrients. Sesquiterpene lactones present in the plant's leaves and responsible for a bitter taste, promote the appetite and stimulate the secretion of bile. For many consumers that trait is not desirable thus in order to enhance the taste, endive plants are subjected to the bleaching treatment or self-bleaching varieties are cultivated. Bleached leaves are crisp, of yellow-green colour and have delicate taste or taste partly deprived of bitterness. Endive is also a source of ascorbic acid, carotenoids and flavonoids, valued in dietetics for their antioxidant properties The protective effects of vegetables and fruit may be contributed by their antioxidant content. High biological value of the species is also proved by low content of compounds which are harmful to health. An excessive content of nitrates in vegetables is not undesirable because resulting from their reduction there appear nitrites and nitro-compounds which are harmful to consumer's health. Obtaining vegetables with high biological value includes many cultivation factors, such as cultivar, microclimatic conditions, soil and rational fertilization. In green houses, endive is cultivated either in a traditional way or by using a soilless systems in form of horticultural or hydroponic substrates.

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

Tthe experiments were carried out in a greenhouse with the controlled microclimate in the years 2009 and 2010 at Warsaw University of Life Sciences. Four endive cultivars obtained from Rijk Zwaan, three crispum leaf cultivars: 'Galanti', 'Perceval' and 'Barundi' and one latifolium leaf cultivar (escarole chicory) – 'Kethel'. 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 x 15 x 7.5 cm (length x width x height). Ten days before the harvest half of the plants were subjected to bleaching by being covered with black foil tunnels. The experiment was established in random design, with three replications and 15 plants in each. The four week old endive seedlings were replanted on the growing slabs 5 plants on each. Fertigation for plants contained 140 mg dm^{-3} of nitrogen in the form of ions NO3-. The nutrient solution in 1 dm3 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 rockwool slab. Last week before the harvest the plants were being only watered and no nutrient solutions were applied. For chemical analysis were selected randomly after 5 of market maturity plants from each replication. The plants were examined for the dry matter content and chemical quality attributes of endive. Dry matter was determined by drying leaf samples in an oven at 105 °C. In endive leaves the content of ascorbic acid (AA) was determined using the Tillmans' method, the content of total soluble solids (TSS) using the digital refractometer and total sugars (TS) were analyzed according to the Luff-Schoorl method. Nitrate (NO3) content was determined spectrophotometrically, the content of P with the colorimetric test and the content of K and Ca with the flame method. The total content of phenolic acids (TCPA) in raw material was determined spectrophotometrically after water extraction according to the Polish Pharmacopoeia VI (2002). The result was calculated in % for caffeic acid. The antioxidant activity was determined by using two methods DPPH and FRAP. DPPH scavenging activity of examined extracts was carried out according to Chen et al. (1997) assay. FRAP was examined according to Benzie and Strain (1996,1999).

Statistical analysis was performed using two-way analysis of variance. Results for individual years were regarded as repetitive values in a statistical test. Detailed comparison of means was performed by the Tukey's test at the significance level of α=0.05.

RESULTS

The bleaching treatment fundamentally changed the composition of endive leaves. The not bleached plants showed 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 too. Only the bleached endive plants grown on coconut fiber had higher contents of ascorbic acid when compared to the unbleached plants. Each group of the bleached endive plants showed a higher content of phosphorus and polyphenolic acids comparing to the unbleached plants, irrespectively the type of substrates studied. Both the bleached and unbleached plants were watered at the end of their vegetation, however the effect of reducing the level of nitrates was noted only for the endive plants cultivated on rockwool.

The plants grown on coconut or wood fiber as well as bleached plants had all similar content of nitrates which was slightly higher comparing to the group of unbleached plants. 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 the bleaching, the content of dry mass, and concentrations of ascorbic acid, potassium, calcium, but also nitrates were the highest (tab. 1).

In the case of endive plants cultivated on rockwool and subjected to bleaching treatment, 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 whether it was a group of bleached or unbleached plants. The antioxidant activity of endive plants measured by FRAP method was higher in average by 40% in favor of the not bleached plants, irrespectively the kind of cultivation substrate used (Fig. 1 b). Lower concentrations of the majority of the compounds studied, certainly caused much lower FRAP values. DPPH values did not decrease significantly after the bleaching, on the contrary they increased in the bleached plants like in these grown on rockwool or, however to a lesser extent, in plants from coconut fiber cultivation.

Different endive cultivars varied in terms of the content of specific compounds and their antioxidant activity (Tab. 2). Leaves of 'Galanti' and 'Barundi' contained more dry mass comparing to 'Perceval' and 'Kethel'. Cultivars as 'Kethel' and 'Galanti' showed highest concentrations of ascorbic acid and polyphenolic acids, 25.3 and 25.7 mg $100g^{-1}$ of fresh mass, and 0.037 and 0.034 %. respectively. The lowest concentration of nitrates were found in leaves of 'Perceval'. The cultivar was characterized by smaller contents of potassium and phosphorus comparing to any other cultivar. 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. The antioxidant activity measured by FRAP decreased rapidly in response to bleaching treatment in all of the tested endive cultivars (Fig. 2 b).

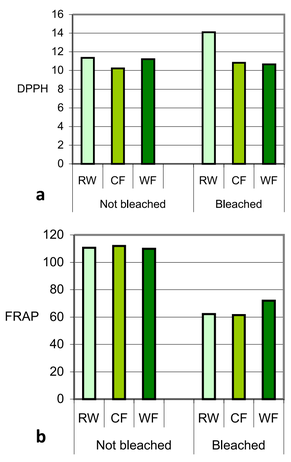

Table 1. Effect of kind of growing medium and bleaching of plants on the selected quality attributes of endyvie plants

Growing medium	Dry matter (%)	AA (mg 100 g^{-1} fw)	TS (g 100 g^{-1} fw)	TSS	TCPA	NO_3	P (mg 100 g^{-1} fw)	K	Ca
Not bleached									
Rockwool	6.3 a*	27.9 a	0.47 b	2.3 b	0.032 a	194.1 a	12.8 b	388.7 b	38.1 ab
Coconut fiber	5.6 b	22.3 b	0.56 ab	2.4 b	0.032 a	218.9 a	13.0 b	434.8 a	41.3 a
Wood fiber	6.0 ab	21.8 b	0.70 a	2.6 a	0.034 a	88.0 b	14.6 a	372.2 b	33.7 b
Mean	6.0	24.0	0.58	2.4	0.033	167.0	13.5	398.6	37.7
Bleached									
Rockwool	4.3 b	15.6 b	0.04 a	1.9 a	0.034 a	141.2 b	38.3 a	305.5 b	20.3 b
Coconut fiber	4.6 a	29.0 a	0.10 a	1.9 a	0.034 a	226.1 a	21.9 b	374.9 a	28.1 a
Wood fiber	4.4 ab	18.1 b	0.07 a	2.0 a	0.035 a	130.6 b	26.0 b	329.6 b	25.8 ab
Mean	4.4	20.9	0.07	1.9	0.034	166.0	28.7	336.7	24.7

*** Note: Mean values for factors which do not differ according to Tukey's HSD test at P=0.05 are marked with the same letters. Interaction insignificant**

Figure 1. a, b. Effect of kind of growing medium and bleaching of plants on the antioxidant activity of endyvie determined by DPPH (%) and FRAP (µmol Fe_3+ g^{-1} fw)

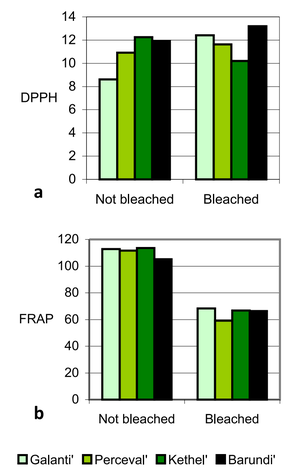

Table 2. Effect of cultivar and bleaching of plants on the selected quality attributes of endyvie plants

Cultivar	Dry matter (%)	AA (mg 100 g^{-1} fw)	TS	TSS	TCPA	NO_3	P	K	Ca
			(g 100 g^{-1} fw)				(mg 100 g^{-1} fw)		
Not bleached									
'Galanti'	6.5 a*	25.7 a	0.57 a	2.6 a	0.034 ab	166.3 ab	14.3 b	414.7 a	37.4 b
'Perceval'	5.5 b	22.3 b	0.58 a	2.4 ab	0.030 b	136.4 b	10.3 d	362.7 b	45.5 a
'Kethel'	5.6 b	25.3 a	0.65 a	2.3 b	0.037 a	174.5 ab	12.7 c	407.8 a	36.4 b
'Barundi'	6.3 a	22.7 b	0.51 a	2.4 ab	0.030 b	190.8 a	16.6 a	409.1 a	31.4 b
Bleached									
'Galanti'	4.5 a	20.3 ab	0.07 ab	2.2 a	0.034 a	165.9 ab	33.5 a	348.9 a	22.4 b
'Perceval'	4.7 a	22.0 ab	0.08 ab	1.8 b	0.034 a	132.2 b	24.3 a	336.3 a	34.3 a
'Kethel'	4.0 b	23.7 a	0.10 a	1.7 b	0.035 a	165.3 ab	26.2 a	319.8 a	18.7 b
'Barundi'	4.5 a	17.7 b	0.02 b	2.0 a	0.034 a	200.7 a	31.1 a	341.7 a	23.7 b

*** See Table 1**

Figure 2. a, b. Effect of cultivar and bleaching of plants on the antioxidant activity of endyvie determined by DPPH (%) and FRAP (µmol Fe_3+ g^{-1} fw)

CONCLUSIONS

The effect of cultivation substrate, cultivar, and bleaching treatment on the quality of the endive appeared diversed. The unbleached endive showed a higher content of dry mass, higher concentrations of sugars, SRSK, potassium, and calcium than the bleached plants, which in turn were characterized by higher concentrations of phosphorus and polyphenolic acids. 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. The endive harvested from substrates as rockwoll or coconut fiber had an elevated level of calcium but was particularly rich in potassium. Considering the effect of bleaching, significant changes were noted in the plants grown on coconut fiber and were expressed by the highest dry mass content, highest concentrations of ascorbic acid, potassium and calcium but also nitrates, among all the group of bleached plants tested. The antioxidant activity of endive plants measured by FRAP method was higher in average by 40% in favor of the not bleached plants, irrespectively the kind of cultivation substrate used. The antioxidant impact of endive plants expressed as DPPH had not been reduced during bleaching treatment. Moreover, when the bleached plants were grown on rockwool it was even intensified. Significant differences were observed when the studied parameters were compared between cultivars.

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