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QUALITY CHARACTERISTICS AND ANTIOXIDATIVE PROPERTIES OF BROCCOLI CULTIVARS (*BRASSICA OLERACEA* L. VAR. ITALICA PLENCK)

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Abstract

GAJEWSKI, M., SZYMCZAK, P., GORCZYCA, M., MADEJSKA, M.: *Quality characteristics and antioxidative properties of broccoli cultivars (Brassica Oleracea L. var. italica Plenck).* Acta univ. agric. et silvic. Mendel. Brun., 2008, LVI, No. 1, pp. 91–96

Quality traits of three broccoli cultivars, which were grown for autumn crop was determined: 'Chevalier' F_1, 'Milady' F_1 (cultivars of Dutch origin) and 'Cezar' F_1 (of Polish origin). Immediately after harvest sensory quality of broccoli was evaluated, using the quantitative descriptive analysis method (QDA). In 'brainstorming' session there were chosen 14 attributes (profiles) concerning smell, texture, taste / flavour. Overall quality impression was also scored and hedonic test of broccoli liking was performed. Other quality traits determined were: antioxidant activity, total carotenoids content, vitamin C content, colour parameters in CIE L*a*b* system. These traits were determined separately for florets and stems of broccoli plants, both of which are usable parts of this vegetable. Results showed that investigated cultivars differed in respect of quality traits concerning sensory attributes, antioxidant activity, carotenoids content, vitamin C content and colour parameters. Results showed also that florets of broccoli performed higher antioxidant activity than stems. Carotenoids content in broccoli cultivars was much higher in florets than in stems, but vitamin C content was on similar level in florets and stems of the plants. Florets and stems of all broccoli cultivars differed much in respect of colour parameters – lightness, greenness and yellowness.

antioxidant activity, broccoli, carotenoids, QDA, quality, sensory quality

Broccoli (*Brassica oleracea* L. var. italica Plenck) is one of few vegetable species which consumption has been increasing rapidly during last decade. It is a result not only of high biological value of this vegetable, but also pleasant flavour. Sensory quality of food is believed to be one of the main factors determining consumer's satisfaction (Abbott, 1999). For detailed description of sensory characteristics of vegetables, the QDA method (quantitative descriptive analysis) is applied. This method relies on evaluation of sensual perception of several attributes (profiles) concerning the taste, smell, texture, colour (Meilgaard et al., 1999). There are approaches to find a relationship between physical and sensory traits of vegetables (Griffiths and Fenwick, 1984; Gajewski, 1999; Gajewski, 2004). For the unification of sensory analytical methods international standards were approved (Anonymous, 1996, 1999).

Another one important quality component is biological value of a product. In the last years more attention was paid to antioxidant activity of vegetables and other food products. Antioxidants are compounds that inhibit or delay the oxidation of other molecules and protect cells against the damaging effects of reactive oxygen species. Antioxidant activity of several plant products has been reported (Velioglu et al., 1998; Elmastas et al., 2007; Paulauskiene et al., 2006). Broccoli is believed to be a vegetable of high antioxidant activity (Wu et al., 2004; Horbowicz and Babik, 2005). There are reports on influence of environmental factors and storage conditions on antioxidative activity of broccoli florets (Leja et al., 2001;

Starzyńska et al., 2003; Jacobsson et al., 2004). Stored broccoli showed higher antioxidant activity, compared with freshly harvested ones, due to accumulation of phenolics during storage (Leja et al., 2001).

Broccoli is also rich in carotenoid compounds. The main carotenoid compound, presented in vegetables, is β-carotene. (Bushway, 1986; Wu et al., 2004; Holden et al., 1999; Anonymous, 2003a; 2003b; Gajc-Wolska et al., 2005; Seroczyńska et al., 2006).

The aim of this work was to study antioxidant activity and some other quality parameters of three different cultivars of broccoli, commonly grown in Poland, and to determine differences in quality between parts of the plant. Also sensory quality of broccoli was investigated to find a relationship between scores for sensory descriptors and overall sensory quality.

MATERIAL AND METHODS

The two-year experiment was performed in the experimental field of Warsaw Agricultural University. Broccoli plants were grown on a medium mud soil, of pH 7.1. Fertilization was applied according to results of soil analysis. Florets with part of a stem (according to the EU quality standard for broccoli) were harvested in the middle of September, at their optimal marketable stage. Three cultivars were chosen for the experiment: 'Chevalier' F_1, 'Milady' F_1 (cultivars of Dutch origin) and 'Cezar' F_1 (of Polish origin).

Quality of broccoli was determined immediately after harvest time. Before evaluation, broccoli were cooked in 0.5% water solution of NaCl for 5 minutes, then cooled to the ambient temperature an put tosmall plastic small containers. Analysis was performed by the trained panel of 12 experts at the sensory laboratory, equipped according to the standard ISO 8589, at two independent sessions. Sensory quality was evaluated using the quantitative descriptive analysis method (QDA). In 'brainstorming' session there were chosen 14 attributes (profiles) concerning smell, texture, taste / flavour. Overall quality impression for broccoli was also scored. Odour attributes were as follows: characteristic odour of boiled broccoli, odour of boiled cabbage, 'grassy' odour, and foreign (non-characteristic for a broccoli) odour. Colour intensity was scored on the scale 'light green – dark green'. Texture attributes (mouthfeel) concerned compactness of the florets ('loose – compact') and firmness ('soft – firm'). Flavour / taste attributes were: characteristic flavour of boiled broccoli, characteristic flavour of boiled cabbage, 'grassy' flavour, sweet taste, sharp (pungent) flavour, foreign flavour. Anchoring points for odour and flavour attributes were: 'the lowest level of intensity – the highest level of intensity'. Intensity of each attribute was estimated on a computer, using non-structural graphical scale. Results were converted to numeric values from 0 to 10 points. Semi-consumer's hedonic test for liking broccoli was also performed by the panel, using the scale with anchoring points: 'I do not like it – I like it very much'.

Antioxidative activity, carotenoids and vitamin C content were determined both for top part of usable part of the plants (florets with flower buds) and for lower part of usable part of the plants (flower stems). Antioxidative activity was determined spectrophotometrically, according to Yen and Chen (1995), as the percent of DPPH (2,2-diphenyl-1-picrylhydrazyl) inhibition in plant methanol extract. Samples were grounded and extracted, using ultrasounds, for 30 min in methanol. Measurements were done after 10 minutes of reaction, using the light wavelength of 517 nm. Total carotenoids content was determined for the same parts of plants, in acetone extracts, by the Shimadzu spectrophotometer, using the wavelength of 450 nm (according to Lichtenthaler and Wellburn 1983). Vitamin C content was determined with titrimetric Tillmans' method. For objective colour determining of florets and stems, HunterLab XE spectrophotometer was used. Colour values were expressed in CIE L*a*b* system, where L* – is lightness (from 0 to 100 units), a* is intensity in red spectrum (+) or green (–), b* is intensity in yellow spectrum (+) or blue (–).

For sensory analysis data compiling the Analsens origin programm was used. Results of the experiment were statistically evaluated by ANOVA, with StatgraphicsPlus 4.1 programm. The homogenous groups of means were identified with LSD test, at probability level $p = 0.05$.

RESULTS AND DISCUSSION

Sensory analysis showed that broccoli cultivars differed in most sensory attributes. In the case of attributes concerning odour, the highest notes for intensity of odour of boiled broccoli got cv. 'Milady' (Tab. I). Odour intensity of this cultivar was scored on the lowest level for odour of boiled cabbage, 'grassy' odour and foreign odour (uncharacteristic for a broccoli). Colour intensity of cv. 'Milady' florets was scored as the most green, and florets of cv. 'Chevalier' as the most compact and firm. In the case of flavour / taste attributes, cultivars differed mostly in 'grassy' flavour, bitter taste, and sharp flavour intensity (Tab. II). The most 'grassy' flavour was typical for cv. 'Cezar', which was also rated as the least sweet, the most bitter and the most sharp, spicy cultivar. Foreign flavour, uncharacteristic for a broccoli, was found only in cv. 'Cezar', but on a low level only. Score for overall sensory quality impression was the highest for cv. 'Milady', a little lower for cv. 'Chevalier', and the lowest for cv. 'Cezar' (Fig. 1). Also hedonic semi-consumer's test of liking showed that cv. 'Cezar' was the poorest cultivar from consumer's point of view.

In order to find the influence of sensory quality descriptors on quality characteristics of broccoli cultivars, the principal component analysis (PCA) was performed. PCA projections for sensory descriptors and cultivars are presented on Fig. 2. The projection shows, that two principal components (PC 1 and PC 2) explain together 100% of the variation between

samples, with the first component alone accounting for 62% of the variation. The relationship between sensory attributes, and between sensory attributes and cultivars, can be determined by their location on the projection. Points A, B and C are situated at different directions from the central point of vectors, what indicates different sensory characteristics of these cultivars. Vector of overall quality (15) has opposite direction compared with vectors of 'grassy' odour, bitter taste, sharp flavour and foreign flavour, so the influence of these quality profiles on the overall sensory quality impression is negative. Positive influence on overall quality exerted such attributes as: florets compactness, flavour of boiled broccoli and sweet taste, which vectors lie close to the vector of overall quality. Sweet taste impression is strictly correlated with overall quality also for green and white cauliflower cultivars, what was found in other report (Gajewski, 1999).

I: *Results of sensory analysis of broccoli – descriptors of odour, colour and texture (scale 0–10)*

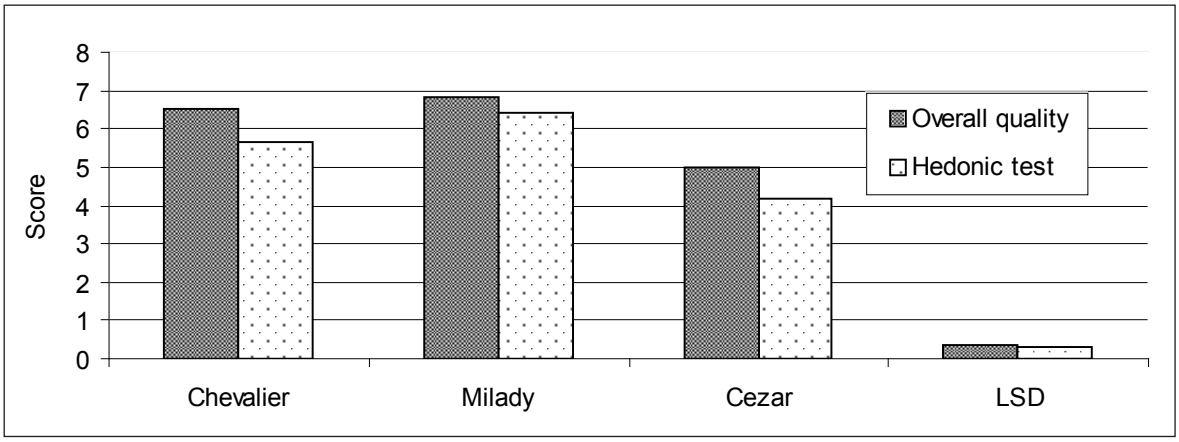
Cultivar	Odour				Florets colour	Florets compactness	Firmness
	of boiled broccoli	of boiled cabbage	'grassy'	foreign			
Chevalier	5.52 a	3.37 b	2.69 b	0.21 b	5.75 a	7.08 b	6.34 c
Milady	7.29 b	2.83 a	2.38 a	0.00 a	6.57 b	6.75 b	5.88 a
Cezar	5.44 a	2.80 a	3.05 b	0.23 b	6.28 b	5.11 a	6.02 b

Explanation: values which do not differ according to LSD test at P = 0.05 are marked with the same letters

II: *Results of sensory analysis of broccoli – descriptors of flavour / taste (scale 0–10).*

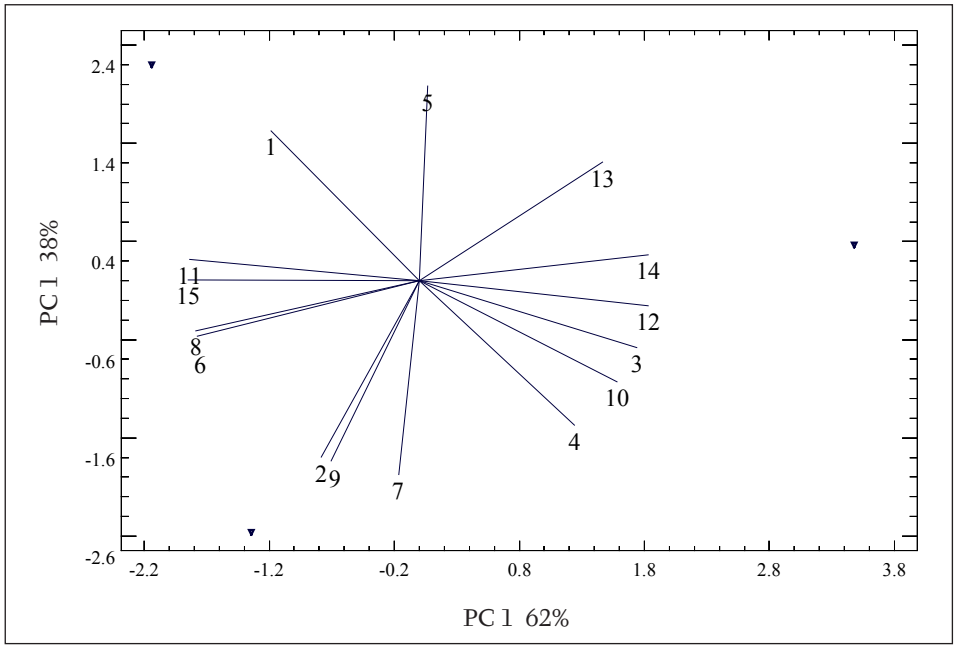
Cultivar	Flavour						
	of boiled broccoli	of boiled cabbage	'grassy'	sweet	bitter	sharp, pungent	foreign
Chevalier	6.04 b	2.56 a	2.61 b	3.45 a	0.72 b	0.63 a	0.00 a
Milady	5.90 b	2.53 a	1.88 a	3.65 b	0.53 a	0.87 b	0.00 a
Cezar	5.02 a	2.53 a	3.03 c	2.85 c	1.24 c	1.11 c	0.41 b

Explanation as in Tab. I



1: *Scores for overall quality and for hedonic test of liking for broccoli cultivars*

Broccoli cultivars showed high antioxidant activity, expressed by percent of DPPH inhibition (Tab. III). 'Cezar' was the cultivar of the highest antioxidative activity. High antioxidant activity of broccoli can be related to high carotenoids and vitamin C content. These compounds are believed to be very active antioxidants (Wu et al. 2004). Carotenoids content in broccoli cultivars varied from 0.68 to 2.21 mg/100 g (mean values of florets and stems). There were also found big differences in carotenoids content between florets and stems (Tab. III). 'Chevalier' was the cultivar of the highest catotenoids content. This cultivar is also one of the richest in flavonoids, according to Horbowicz and Babik (2005). Broccoli florets were richer in carotenoids than stems. According to Holden et al.(1999) and Podsędek (2007),



2: *PCA projection for sensory analysis of broccoli. PC1 – principal component 1, PC2 – principal component 2. Vectors: 1 – odour of boiled broccoli, 2 – odour of boiled cabbage, 3 – 'grassy' odour, 4 – foreign odour, 5 – colour, 6 – florets colour, 7 – florets compactness, 8 – firmness, 9 - flavour of boiled broccoli, 10 – flavour of boiled cabbage, 11 grassy' flavour, 12 – sweet taste, 13 – sharp, pungent flavour, 14 – foreign flavour, 15 – overall quality. Cultivars: A – 'Chevalier', B – 'Milady', C – 'Cezar'.*

total carotenoids content in broccoli varies from 1 to 2.2 mg/100 g, so our results are in accordance to these data. Vitamin C content in investigated cultivars varied from 95 to 111 mg/100 g. This value is quite high as for vegetables, since in most vegetables vitamin C content reach value 50 mg/100 g. Florets of the two cultivars were richer in vitamin C than stems, but in the case of cv. 'Cezar' stems were richer in vitamin C.

Data obtained point out that florets, which show higher antioxidant activity, are at the same time richer in carotenoids than stems. In order to find strict relationship between antioxidative activity and carotenoids or vitamin C content, correlation coefficients between these traits were calculated. However, correlation coefficient *r* between antioxidant activity and carotenoids content was very low (0.14), so the correlation was rather weak. The same can be said about correlation between antioxidant activity and vitamin C content (correlation coefficient *r* equal to 0.15). However, Paulauskiene et al. (2006) found strong correlation between carotenoids content and antioxidant activity fruits of pumpkin cultivars ($r = 0.91$).

Colour of florets and stems of broccoli was differentiated (Tab. III). Broccoli stems showed higher value of L* (lightness), lower value of a* (intensity of green colour) and at the same time higher value of b* (yellowness) than florets. It indicates on lower green pigment (chlorophyll) content in the stem compared with the floret part of the plant. Colour parameters for cultivars were also differentiated. Florets of cv. 'Cezar' showed lower L* value than florets of other cultivars, and also higher value of a*.

III: *Quality traits of broccoli cultivars*

Cultivar	Part of the plant	Antioxidative activity (% DPPH)	Carotenoids content (mg/100 g)	Vitamin C content (mg/100 g)	Colour parameters in CIE L*a*b* system		
					L*	a*	b*
Chevalier	Florets	83.1	2.68	116.2	49.2	–7.2	12.5
	Stem	70.8	1.73	106.0	61.5	–1.5	15.4
Milady	Florets	84.6	1.04	98.0	49.2	–7.7	11.6
	Stem	79.2	0.31	95.3	61.5	–1.4	14.4
Cezar	Florets	83.2	2.16	95.2	52.2	–8.3	13.2
	Stem	82.2	0.30	108.3	48.5	–1.8	14.3

Cultivar	Part of the plant	Antioxidative activity (% DPPH)	Carotenoids content (mg/100 g)	Vitamin C content (mg/100 g)	Colour parameters in CIE L*a*b* system		
					L*	a*	b*
Means for cultivars	Chevalier	77.0 a	2.21 c	111.1 b	55.4 a	–4.4 a	14.0 b
	Milady	77.7 a	0.68 a	96.7 a	55.4 a	–4.6 ab	13.0 a
	Cezar	81.9 b	1.23 b	95.3 a	49.8 b	–4.9 b	13.8 b
Means for parts of plant	Florets	83.6 b	1.96 b	103.1 a	50.2 a	–7.7 b	12.4 a
	Stem	77.4 a	0.78 a	103.2 a	57.2 b	–1.6 a	14.7 b

Explanation: as in Tab. I.

SOUHRN

Kvalitativní charakteristiky a antioxidační vlastnosti kultivarů brokolice (*Brassica Oleracea* L. var. italica Plenck)

Brokolice je v poslední době velmi populární v lidské výživě, proto její výživová a biologická hodnota je důležitým aspektem. Naše výzkumy prokázaly, že kultivary brokolice se liší v kvalitě, koncentraci živin, aktivitě antioxidantů, obsahu vitaminu C a obsahu barviv. Též kvalita stonků a květů se u jednotlivých kultivarů lišila. V případě obsahu antioxidantů byl obsah vyšší v květenství puků než u stonku. Obsah karotenoidů byl vyšší v květenství než ve stoncích, ale vitamin C byl na stejném stupni ve stoncích i květenstvích. Květenství a stonky se lišily v barevných parametrech chlorofylu A a B. Květenství i stonky jsou jedlými částmi brokolice a dá se říci, že mají pozitivní nutriční i biologickou hodnotu v lidské výživě.

antioxidační charakteristika, brokolice, karotenoidy, QDA, kvalita, senzorická kvalita

SUMMARY

Broccoli is a very popular element of human diet these days, so its nutritional and biological value has a very important aspect. Our investigations showed that broccoli cultivars differed in some quality traits, concerning sensory characteristics, antioxidant activity, carotenoids content, vitamin C content and colour parameters. Also quality characteristics of florets and stems of plants was differentiated. In the case of antioxidant activity, florets of broccoli showed higher value than stems. Carotenoids content in broccoli was much higher in florets than in stems, but vitamin C content was on similar level in florets and stem. Florets and stems of all broccoli cultivars differed in colour parameters in CIE L*a*b* system. Since florets, as well as stems, are usable parts of broccoli plant, it can be said that both parts of the plant have high nutritional and biological value for human.

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