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IMPROVEMENT OF NUTRACEUTICAL VALUE OF BROCCOLI SPROUTS BY NATURAL ELICITORS

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Abstract. Contrary to genetic engineering elicitation is a cheaper and socially acceptable methods for improving plant food functionality. In this work broccoli sprouts were elicited with *Saccharomyces cerevisiae* (SC) and *Salix daphnoides* bark (SD) extracts. The most effective elicitors of phenolics overproduction were 1% SD and 0.5% SC. Treatment with 0.1% SC significantly increased content of ferulic acid, whereas *p*-coumaric and syryngic acids levels were significantly elevated by elicitation with SC (0.5% and 1%) and SD. All studied extracts appeared to be very effective elicitors of kaempferol biosynthesis (17-fold for 0.1% SC). In the case of mastication-extractable phytochemicals significant increase of SOD-like activity was observed after elicitation with 0.1% SC, 1% SC and 1% SD. All elicitors caused also an increase of $OH^{\bullet}$ radicals scavenging ability. The most effective was 1% SC, where an increase was about 40%. Elicitation significantly improved potential bioaccessibility of compounds with anti-ROS activities, especially SOD-like active phytochemicals, thus may consist an effective biotechnology.

Key words: elicitation, broccoli sprouts, phenolic compounds, $OH^{\bullet}$ radicals, antioxidant activity

INTRODUCTION

Free radicals and the resultant oxidative stress on an organism have been the subject of analysis for clinicians, nutritionists, biologists and chemists alike. Of all the reactive oxygen species (ROS), the hydroxyl reactive oxygen species is known to be one of the most reactive and physiologically harmful, suspected in such pathologies as atherosclerosis, oncogenesis, cataractulargenesis and DNA mutation [Halliwell and Gutteridge 1993, Halliwell et al. 1992, Malins 1993].

In living organisms there are two major reactive oxygen species, superoxide radical and hydroxyl radical that are being continuously formed in a process of reduction of oxygen to water. In the Haber-Weiss reaction hydroxyl radicals are generated in the

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presence of hydrogen peroxide and iron ions. The first step involves reduction of ferric into ferrous ion:

$$Fe^{3+} + {}^{\bullet}O^{2-} \rightarrow Fe^{2+} + O_2 \quad (1)$$

The second step is the Fenton reaction:

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + OH- + {}^{\bullet}OH \quad (2)$$

The requirement of hydrogen peroxide in the Fenton reaction led to the misleading concept of oxidative stress that ignores the fact that hydroxyl radical (•OH), known to be the most biologically active free radical, is formed *in vivo* under hypoxic conditions [Michiels 2004]. Moreover, this free radical can be generated *in vitro* under the reducing condition in the presence of ascorbic acid and iron ions.

Recent studies have demonstrated that the regular consumption of fruits and vegetables may reduce the risk of developing chronic health conditions, including cardiovascular diseases and different types of cancer. There are many evidences that these food properties are mainly bound with a high capacity to scavenge ROS and, in consequence, to prevent cells against oxidative damage [Fahey and Kensler 2007].

Brassicaceae plants are one of the most popular vegetables consumed all over the world and considered to be a good source of bioactive phytochemicals. Additionally, *Brassica* species and varieties are increasingly becoming a research model in plant science, as a consequence of the importance of their primary and secondary metabolites. *Brassica* foods (e.g., broccoli, Brussels sprouts, cabbage, cauliflower, etc.) provide important nutrients such as provitamin A, vitamins C, E, K, folic acid, calcium, potassium, as well as phenolic compounds and glucosinolates [Singh et al. 2004]. It has been widely reported that sprouts provide higher nutritive value than raw seeds and their production is simple and inexpensive. Sprouts have long been used in the diet as "health food". Recent research shows that in addition to being a good source of nutritional compounds they also have important phytochemicals with disease preventive and health promoting properties [Randhir et al. 2004].

Improvement of nutritional and nutraceutical value of plant/sprouts will be beneficial for human health. The aim can be reached in two main ways: genetic manipulation and modification of metabolism by elicitors. Genetic engineering of plant food has proven to be controversial. Modification of chemical composition and selected bioactivities of plant food by elicitors is cheaper and socially acceptable. Sprouting seeds may be regarded as a natural bioreactor or biotechnological module [Gawlik-Dziki et al. 2012]. Seed and seedlings treatments for improving plant vigour are being developed and used. Increasingly, commercial seed treatment approaches are beginning to view seed treatments as a means to increase substantially the value of the seed and to improve plant growth and productivity [Andarwulan and Shetty 1999].

The hypothesis of this research is that the phenolic overproduction, enhancement of hydroxyl radicals scavenging ability and SOD-like activity of Broccoli sprouts can be stimulated by treatment of seedlings with natural elicitors: autoclaved cultures of yeast (*Sacchcaromyces cerevisiae*) and water extracts of *Salix daphnoides* bark.

MATERIALS AND METHODS

Induction of broccoli sprouts metabolism was performed according to g regre with some modification.

Elicitors were prepared as follow: 1) Instant yeast *Saccharomyces cerevisiae* L. (SC) was dissolved in distilled water at concentration of 0.1, 0.5 and 1% (w/v) and autoclaved. 2) Bark of *Salix daphnoides* (SD) (obtained from ecological farm, Poland) were dried, pulverized in laboratory meal according to procedure described by Dziki and Laskowski [2010] and extracted with boiling water in ratio 1:100 (w/v).

Dry seeds of broccoli (var. Cezar) were sterilized with 1% sodium hypochloride solution for 5 min and rinsed with sterile water. Disinfected seeds were imbibied for 6 h at 25^{o}C in water and then placed (on a layer of wet filter paper (Whatman Grade No. 2 UK) in plastic Petri dishes. Germination tests were performed using triplicate samples (each containing 50–60 seeds). Germination was carried out at 25°C in darkness. The germinating seeds were watered with distilled water, 6 ml/24h. After 2nd, 3rd, at 4th day of germination sprouts were watered with elicitors. Six-day-old sprouts were gently collected and used for extracts preparation. One gram of fresh sprouts was homogenized with 7 ml of methanol: water (1:1, v/v) solution (chemical extract) or phosphate buffered saline pH = 7.2 (PBS, buffer extract). Samples were shaken at room temperature for 60 min and centrifuged at 8000 rpm (8640 rcf) for 10 min. Extraction was repeated, adequate supernatants were collected and used for further analyses.

The content of phenolic acids and selected flavonoids was analysed following the HPLC method [Świeca et al. 2012]. A Varian HPLC separation module (Varian, Palo Alto, CA) equipped with Varian ChromSpher C18 (25 × 4.6 mm) column and ProStar 325 UV-Vis Detector was used. The mobile phase contained solvent A (1% acetic acid) and solvent B (100% methanol). The solvent gradient was programmed as follows: at 0 min, 5% B; 5 min, 5% B; 15 min, 15% B; 30 min, 30% B; 40 min, 35% B; 50 min, 70% B; 55 min, 100% B. At the end of gradient the column was washed with 100% methanol and equilibrated to initial condition. Detection was performed at 290 and 320 nm. Phenolic compounds in sample were identified by comparing their retention times with those of the standard compounds.

Hydroxyl radicals were generated by Fenton reaction in the system of $FeSO_4$ and H_2O_2 [Su et al. 2009]. The reaction mixture was consisted of 0.5 ml $FeSO_4$ (8 mM), 0.8 ml H_2O_2 (6 mM), 0.5 ml distilled water, 1.0 ml of extract and 0.2 ml sodium salicylate (20 mM). The total mixture (3.0 ml) was incubated at 37^{o}C for 1 h and then the absorbance of the mixture was recorded at 562 nm. The scavenging activity was calculated using the following equation:

$$\text{Scavenging rate } \% = [1-(A_1-A_2)/Ac] \times 100$$

where: Ac is the absorbance of the control (without extract), A_1 is the absorbance of the extract addition and A_2 is the absorbance without sodium salicylate.

Assay for superoxide dismutase (SOD)-like activity was analysed following the method described by Marklund and Marklund [1974]. The reaction mixture was prepared by mixing 0.2 ml of the sample solution, 2.6 ml of the Tris-HCl buffer

(50 mM TRIZMA + 10 mM EDTA, pH 8.5), 0.2 ml of 7.2 mM pyrogallol and stood at 25°C for 10 min. The oxidized pyrogallol was measured at 420 nm after stopping the reaction by adding 0.1 ml of 1.0 N HCl. The SOD-like activity was calculated using the following equation:

$$\text{SOD-like activity \%} = [1-(As/Ac)] \times 100$$

where: As – absorbance of tested sample, Ac – absorbance of control

For indicating the bioactivity of potentially bioaccessible phenolic compounds the relative antioxidant efficiency factor (REF) was calculated:

$$REF = A_{CE}/A_B$$

where: A_B – IC_{50} of buffer extract, A_{CE} – IC_{50} of chemical extract.

All experimental results were mean ± S.D. of three parallel experiments (n = 9). The obtained data was subjected to a statistical analysis and the consequent evaluations were analyzed for a variance analysis. The statistical differences were estimated through Tukey's test. Statistical tests were evaluated by using the Statistica 6.0 software (StatSoft, Inc., Tulsa, USA). All the statistical tests were carried out at a significance level of $p = 0.05$.

RESULTS AND DISCUSSION

In particular some biotic and abiotic elicitors can result in an enhancement of the specific secondary metabolite production. Under these conditions a number of signal pathways can be pre-activated by salicylic acid (SA), jasmonic acid (JA), ethylene or abscisic acid pathways, which are generally involved in the defence responses. As an example, due to aforementioned factors, plant cells activate the chorismate pathway that also results in changes in the plant phenolics [Jahangir et al. 2009]. Natural source of salicylates was a salix species. *S. daphnoides* Vill., *Salix purpurea* L., and *S. alba* L. were considered to be potential natural source of salicylates [Sugier et al. 2011]. Previous study proved that *Salix daphnoides* water extract were an effective elicitor for improving antioxidant potential of broccoli sprouts [Gawlik-Dziki et al. 2012].

As it can be seen from Table 1, elicitors used in these studies significantly influenced on the phenolics profile of broccoli sprouts. All used elicitors caused a significant decrease of chlorogenic acid content (about 50–67% of control). Also content of *p*-hydroxybenzoic acid decreased significantly after elicitation by SC extracts. Treatment with 0.1% SC extract significantly increased a content of ferulic acid, whereas for the other elicitors a significant decrease of its level was observed. SC extract at concentrations of 0.1% and 1% had no significant effect on the sinapinic acid and (+)-catechin level, whereas caused a significant decrease of quercetin content. It worth noting that *p*-coumaric and syryngic acids levels were significantly elevated by elicitation with SC (0.5% and 1%) and SD extracts. The increase of synapinic acid level was observed only in the case of sprouts treated with SD extract, whereas caffeic acid level was increased in the higher degree by treatment with SD and 0.5% SC extracts. In the light of data

Table 1. Changes of phenolic profile of elicited broccoli sprouts
Tabela 1. Zmiany w profilu polifenolowym elicytowanych kiełków brokułu

Compound – Związek µg/g FM	Control Kontrola	Elicitor – Elicytor			
		SC* 0.1%	SC+ 0.5%	SD++ 1%	SD**1%
(+)-catechin (+)-catechina	17.41 ±0.32[a]	17.21 ±0.41[a]	38.52 ±2.22[b]	17.32 ±1.98[a]	54.29 ±4.55[c]
p-hydroxybenzoic acid Kwas *p*-hydroksybenzoesowy	7.85 ±0.09[d]	3.33 ±0.06[b]	6.07 ±0.08[c]	1.43 ±0.96[a]	9.07 ±0.79[e]
Chlorogenic acid Kwas chlorogenowy	16.24 ±0.41[c]	8.12 ±0.10[a]	10.83 ±0.31[b]	8.28 ±0.74[a]	8.32 ±0.15[a]
Caffeic acid Kwas kawowy	3.67 ±0.05[a]	3.53 ±0.05[a]	14.69 ±0.72[d]	1.73 ±0.06[b]	10.20 ±0.27[c]
Syryngic acid Kwas syryngowy	1.57 ±0.07[c]	0.98 ±0.09[b]	1.97 ±0.07[d]	4.42 ±0.99[a]	4.67 ±0.17[a]
p-coumaric acid Kwas *p*-kumarowy	40.18 ±2.19[a]	40.48 ±2.68[a]	62.50 ±3.82[b]	66.96 ±7.11[b]	89.28 ±8.11[c]
Ferulic acid Kwas ferulowy	12.21 ±0.41[c]	16.28 ±0.49[d]	3.58 ±0.08[b]	6.41 ±0.88[a]	7.59 ±0.33[a]
Synapinic acid Kwas synapinowy	10.47 ±0.38[a]	10.62 ±0.32[a]	9.04 ±0.66[b]	10.47 ±0.42[a]	12.21 ±0.68[c]
Quercetin Kwercetyna	15.16 ±0.65[c]	13.17 ±0.55[b]	32.59 ±2.88[e]	10.31 ±0.39[a]	20.56 ±1.12[d]
Kaempferol Kempferol	0.39 ±0.01[b]	6.61 ±0.08[d]	2.42 ±0.99[a]	2.59 ±0.22[a]	1.55 ±0.68[c]

* *Saccharomyces cerevisiae*
***Salix daphnoides*
[a, b, c] – means followed by different letters are significantly different at $p < 0.05$. Each value represents the mean of 3 measurements (±SD) – wartości średnie oznaczone różnymi literami różnią się statystycznie istotnie przy $p < 0,05$. Wartości średnie obliczono z 3 powtórzeń (±SD)

given in the Table 1 is clearly visible that elicitation had a large influence on sprouts flavonoids composition. Both (+)-catechin and quercetin level were significantly increased only after elicitation by 0.5% SC and 1% SD extracts. Contrary, all studied extracts appeared to be a very effective elicitors of kaempferol biosynthesis in sprouts (17-fold for 0.1% SC). In conclusion, taking into account all analysed phenolic compounds, the most effective elicitors were 1% SD and 0.5% SC extracts. Comparison of HPLC phenolic profiles of sprouts treated with 0.5% SC and control (non-treated) was performed in Fig. 1.

Regardless of growing interest of pro-healthy plant-derived food, especially sprouts, there are lack of comprehensive studies concerning phenolics profile of broccoli sprouts. *Brassica* species have been shown to contain quercetin and kaempferol as main flavonoid compounds, mainly occur as glycosides (quercetin 3-O-sophoroside and kaempferol 3-O-sophoroside) [Vallejo et al. 2004]. Hydroxycinnamic acid derivatives such as sinapic and ferulic acid derivatives, accounted by over 25% of the total content and caffeoyl-quinic acid derivatives (mainly neochlorogenic and chlorogenic acids) were determined in much smaller amounts in the broccoli sprouts [Moreno et al. 2008].

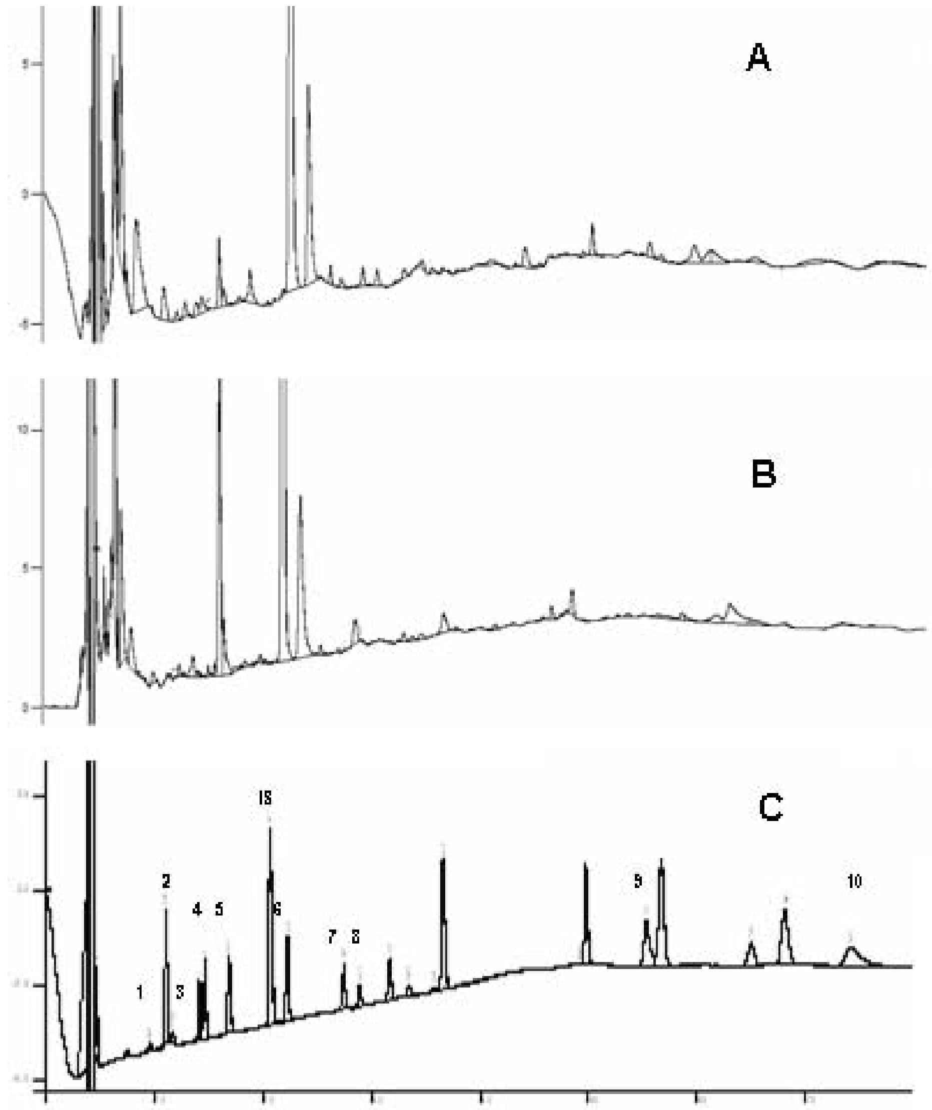

Fig. 1. HPLC chromatogram of extract from broccoli sprouts elicited by 0.5% SC extract (A), control (non-elicited) sprouts (B), and standard compounds (C): 1 – (+)-catechin, 2 – *p*-hydroxybenzoic acid, 3 – chlorogenic acid, 4 – caffeic acid, 5 – syryngic acid, 6 – *p*-coumaric acid, 7 – ferulic acid, 8 – sinapinic acid, 9 – quercetin, 10 – kaempferol, IS – internal standard

Rys. 1. Chromatogram HPLC ekstraktu z kiełków brokułu elicytowanych 0,5% ekstraktem z SC (A), kiełków kontrolnych (B) i związków wzorcowych (C): 1– (+)-katechina, 2 – kwas *p*-hydroksybenzoesowy, 3 – kwas chlorogenowy, 4 – kwas kawowy, 5 – kwas syryngowy, 6 – kwas *p*-kumarowy, 7 – kwas ferulowy, 8 – kwas synapinowy, 9 – kwercetyna, 10 – kempferol, IS – standard wewnętrzny

Plant interaction with environmental stress factors including animals and insects herbivores, pathogens, metal ions, light, among others, is known to lead to the activation of various defence mechanisms resulting in a qualitative and/or quantitative change in plant metabolite production. Andarwulan et al. [1999] tested acetyl salicylic acid and fish protein hydrolyte as natural elicitors for improving of pea (*Pisum sativum*) seed vigour response. Influence of peptide elicitors- fish protein hydrolisate, lactoferrin and phytochemical elicitor- oregano extract on phenolic stimulation in dark germinated mung bean sprouts was studied by Randhir et al. [2004]. In our study yeast extract was a source of polysaccharides, whereas SD extract was a source of salicylic acid derivatives.

Perez-Bablibrea et al. [2011b] proved that elicitation of broccoli sprouts with salicylic acid solution increased the flavonoids, sinapic and ferulic acid derivatives levels. In contrast, in our study treatment with SD extract caused significant decrease of ferulic acid and increased caffeic acid content. Cited investigators observed also, similarly to our studies, reduction of caffeoyl-quinic acid derivatives after the salicylic acid treatments. Unexpectedly, treatment of sprouts with chitosan did not influence on the phenolic composition [Perez-Bablibrea et al. 2011b]. Contrary to this, SC extract used in our study significantly modified phenolic profiles of broccoli sprouts (tab. 1).

Differences in phenolic contents observed between studies could be the result of multiple factors, including methodology (all reports used different approaches for extraction, chromatography, and quantification), sample characteristics and conditions, including variables such as growth and storage environments [Brown et al. 2002]. As it can be seen from the Table 1, broccoli sprouts were a good dietary source of *p*-coumaric, ferulic and caffeic acids. It might be speculated that elevation of these lignin biosynthesis intermediates contents was bound with cross-talk response to the stress conditions [Solecka 1997, Fujita et al. 2006]. Additionally, high levels of *p*-coumaric acids might be involve in overproduction coumarylCoA, a key compound in flavonoids biosynthesis [Zabala et al. 2006].

There is many evidence that free radicals cause oxidative damage to DNA, proteins, and lipids contributing significantly to aging and degenerative diseases such as cancer, cardiovascular disease, immune system decline, brain dysfunction (e.g. Alzheimer's disease) and cataracts. Antioxidants are compounds that have the ability to scavenge free radicals, especially ROS [Randhir et al. 2004]. Phenolics compounds were considered as main antioxidants and health-beneficient secondary plant metabolites, there are only several studies concerning antioxidant potential of broccoli sprouts [Perez-Bablibrea et al. 2011a, b]. It should be noted that in studies performed by Sengul and coworkers [Sengul et al. 2009] no direct correlations between their concentration and antioxidant activity were found. Jacobs et al. [2009] have recently emphasized that the whole food, and particularly a combination of various natural food products, has a stronger health effect that any single biochemical or their combination. These authors conclude that the public may be better served by focusing on whole foods than on individual nutrients included in them. Moreover, there is no complete knowledge of food composition, and some effects may result from unidentified components. Thus, in our study, activities of buffer – extractable (potentially mastication – extractable and bioaccessible) and chemically extracted compounds were estimated and compared.

ROS such as $O_2^{\cdot-}$, H_2O_2, and OH• are incessantly generated inside the human body as a consequence of the exposure to multitude of exogenous chemicals in our ambient environment and/or a number of endogenous metabolic processes involving redox enzymes and bioenergetics electron transfer, eg. a potential source of ROS are leukocytes activated during inflammatory responses [Lipton 1999, Zhao et al. 2006].

Elicitation significantly influenced on SOD-like activity of broccoli sprouts. As it can be seen in Fig. 2, in control samples a significantly higher activity was determined for chemical extract. After elicitation activity of chemically extractable phytochemicals decreased significantly, especially after treatment with 0.5% SC. Contrary to these results, in the case of mastication-extractable phytochemicals significant increase of SOD-like activity was observed after elicitation with 0.1% and 1% SC and 1% SD extracts, whereas 0.5% SC had no significant effect.

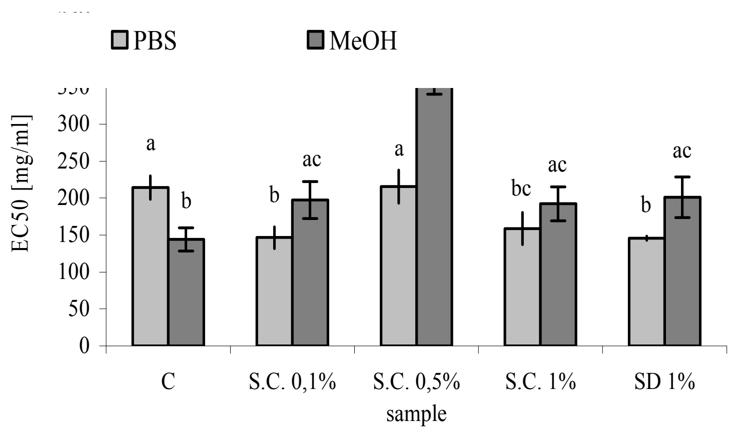

Fig. 2. Changes of SOD-like activity of broccoli sprouts as consequence of elicitation: a, b, c – means followed by different letters are significantly different at $p < 0.05$. Each value represents the mean of 3 measurements (±SD)

Rys. 2. Wpływ elicytacji na aktywność zbliżoną do SOD: a, b, c – wartości średnie oznaczone różnymi literami różnią się statystycznie istotnie przy $p < 0,05$. Wartości średnie obliczono z 3 powtórzeń (±SD)

The superoxide anion changes into a hydroxyl radical by the catalytic action of contaminating trace iron, so that the amount of hydroxyl radicals is a consequently relatively larger than that of superoxide anions. As in can be seen in Fig. 3. all tested samples possessed a high ability to neutralize OH radicals. Taking into account chemical extracts should be noted that the highest activity was observed for control samples, elicitation caused a statistically significant decrease of studied activity. Most importantly, all elicitors used in this study caused an increase of antiradical activity potentially mastication-extractable phytochemicals. The most effective elicitor was 1% SC extract, where an increase was about 40%.

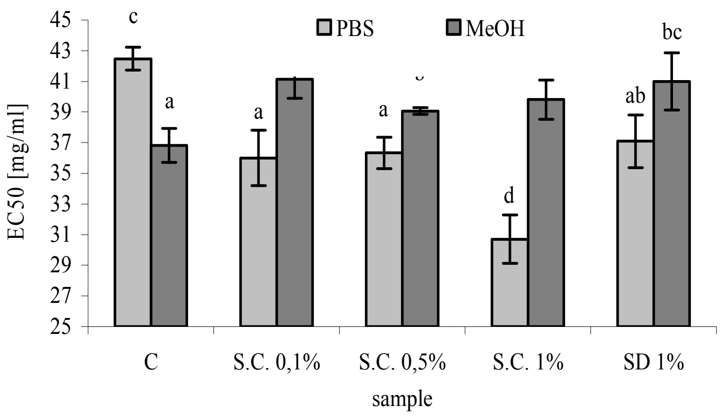

Fig. 3. Changes of ability to OH radical scavenge as consequence of elicitation: a, b, c – means followed by different small letters are significantly different at $p < 0.05$. Each value represents the mean of 3 measurements (±SD)

Rys. 3. Wpływ elicytacji na zdolność do neutralizacji rodników hydroksylowych: a, b, c – wartości średnie oznaczone różnymi literami różnią się statystycznie istotnie przy $p < 0,05$. Wartości średnie obliczono z 3 powtórzeń (±SD)

As shown in the Fig. 4, elicitation significantly improved potential bioaccessibility of compounds with anti-ROS activities (in the comparison with control samples). This influence is especially strongly visible in the case of SOD-like active phytochemicals.

Best known and already used in clinical practice is resveratrol, which neutralizes hydroxyl radicals by means of the aromatic hydroxylation reaction. Similar action against hydroxyl radicals is exerted by ferulic acid that belongs to the family of hydroxycinnamic acid with the chemical structure similar to curcumin [Srinivasan et al. 2007]. Ferulic acid is found in leaves and seeds of many plants, especially in brown rice, whole wheat, oats, apples, artichokes, oranges, and pineapples. Curcumin (turmeric yellow) exerts anti-inflammatory activity, prevents atherosclerosis, and has protective action on brain [Lipiński 2011]. Based on the results showed in Table 1, it could be seen that ferulic acid level was significantly increased by treatment sprouts with 0.1% SC extract, simultaneously buffer extract obtained from this sprouts possessed significantly higher ability to OH radical scavenge and SOD – like activity (with comparison to control). On the other hand, elevation of anti-ROS activity was observed also in the case of sprouts treated witch 1% SC, contained relatively low amounts of ferulic acid. Additionally, all used elicitors, caused significant increased of kaempferol level- flavonoid with strong anticancer activity. Also *p*-coumaric acid, compounds with anticancer activity [Mohammad et al. 2009] was induced by treatment with SC extracts, whereas treatment with SD did not influenced on their level. Most importantly, increase of ROS-scavenging activity was observed for buffer extractable-potentially bioaccessible compounds, similarly to results previously published by Gawlik Dziki et al. [2012]. It could be suggested that hydrophilic compounds may be effectively extracted during mastication and thus, in gastrointestinal system.

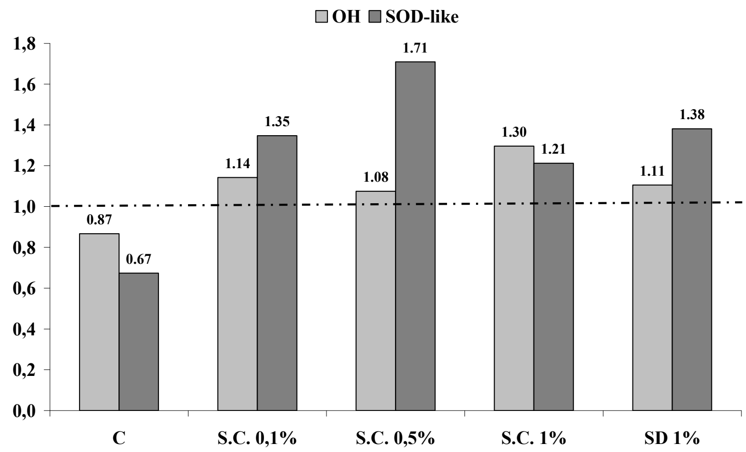

Fig. 4. Effect of elicitation on the relative antioxidant efficiency factor (REF)
Rys. 4. Wpływ elicytacji na wartość relatywnego współczynnika efektywności przeciwutleniaczy (REF)

Our results showed that elicitation of broccoli sprouts with SC and SD is an effective and safe way to get food, which is an excellent source of phenolic compounds, reaching higher values than those found in others sprouting species, and even richer than the commercial broccoli florets. In the light of food synergy concept, it seems reasonable to assume that treatment with natural elicitors proposed in this work significantly improve health-beneficent properties of easy-to-eat broccoli sprouts and may consist acceptable alternative to genetic modification not acceptable by many consumers.

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ZWIĘKSZENIE WARTOŚCI NUTRACEUTYCZNEJ KIEŁKÓW BROKUŁU POPRZEZ ZASTOSOWANIE ELICYTORÓW BIOTYCZNYCH

Streszczenie. W przeciwieństwie do inżynierii genetycznej modyfikacja przy użyciu elicytorów jest tania i społecznie akceptowalna. W niniejszej pracy kiełki brokułu były elicytowane wodnymi ekstraktami z drożdży *Saccharomyces cerevisiae* (SC) i kory wierzby purpurowej *Salix daphnoides* (SD). Nadprodukcja związków fenolowych została spowodowana przez 1% (w/v) ekstrakt z SD i 0,5% (w/v) ekstrakt z SC. Działanie 0,1% ekstraktem z SC spowodowało istotny wzrost zawartości kwasu ferulowego. Zawartość kwasów *p*-kumarowego i syryngowego wzrosła istotnie po elicytacji 0,5 i 1% ekstraktami z SD. Wszystkie zastosowane roztwory spowodowały wzrost zawartości kempferolu (ponad 17-krotny w przypadku 0,1% SC). Statystycznie istotny wzrost zdolności do neutralizacji rodnika ponadtlenkowego przez związki potencjalnie biodostępne zaobserwowano po elicytacji roztworami: 0,1% SC, 1% SC i 1% SD. Wszystkie elicytory spowodowały istotny wzrost zdolności do neutralizacji rodnika hydroksylowego. Najbardziej efektywnymi elicytorem był 1% ekstrakt z SC (ponad 40% wzrost aktywności). Elicytacja znacząco zwiększyła potencjalną biodostępność związków zdolnych do neutralizacji reaktywnych form tlenu – może więc stanowić efektywną technikę biotechnologiczną.

Słowa kluczowe: elicytacja, kiełki brokułu, związki fenolowe, rodnik hydroksylowy, aktywność antyoksydacyjna

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