Changes in antioxidant activity induced by irradiation of clove (*Syzygium aromaticum*) and ginger (*Zingiber officinale*)

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Summary

Antioxidant properties of clove (*Syzygium aromaticum*) and ginger (*Zingiber officinale*) irradiated by doses of 5, 10, 20 and 30 kGy, respectively, were studied in methanolic extracts of treated spices. Ability of the extracts of both spices to quench the 2,2-diphenyl-1-picrylhydrazyl free radical was not affected immediately after irradiation of clove and ginger. After a month of irradiated ginger storage, the antiradical activity gradually increased mainly at a dose of 20 kGy. Irradiation did not cause a change in the total contents of phenolic compounds in spices immediately after radiation treatment, but during the ginger storage their contents increased, mostly in ginger irradiated at 20 kGy. In both spices, irradiation caused an increase in the contents of oxidative substances, which was proportional to the intensity of radiation, but the differences slowly vanished during the post-irradiation storage of spices. The reducing power of clove and ginger remained the same as in the unirradiated samples at all used doses of radiation. Influence of storage for five months alone on the antioxidant activity of these spices was more intensive than the radiation treatment, and resulted in an increase in the antiradical activity, reducing power and contents of total phenolic compounds in ginger, and in a slight reduction of the reducing power, contents of total phenolic compounds and oxidative substances in clove.

Keywords

clove; ginger; irradiation; antioxidant properties

Irradiation and heat treatment of various food products including spices has for many years been used for insect disinfections and microbial decontamination, and as a means of preserving foods. In recent years, it has been acknowledged that many spices not only have properties that make food more pleasant and tastier but also show potential human health benefits with their important preservative and antioxidant properties. There has been a marked increase in the literature on antioxidant properties of herbs and spices. Several common spices are now understood to exert strong antioxidant activity, but little information is available on the extent of destruction of their antioxidant compounds during their treatment by the action of irradiation or heat processing. In this context, our previous research was focused on the study of changes in the antioxidant activity of some spices during their irradiation and heat treatment [1-5]. This article presents the results of investigation on changes in the antioxidant activity of irradiated powdered dry clove (*Syzygium aromaticum*) buds and ginger (*Zingiber officinale*) roots.

Processing by ionizing radiation is recognized as an effective method to maintain the quality of spices for a long time. The Directive 1999/3/EC [6] established a Community list of foods and food ingredients that may be treated by ionizing radiation. Maximum overall average absorbed dose may be 10 kGy for dried aromatic herbs, spices and vegetable seasonings. According to Codex Alimentarius General Standard [7] for irradiated foods, the maximum absorbed dose delivered to a food should not exceed 10 kGy, except when necessary to achieve a legitimate technological purpose. Limitation of FDA for culinary herbs, seeds, spices, vegetable seasonings and blends of these aromatic vegetable substances has not to exceed 30 kGy [8].

Ginger and clove are known for their strong antioxidant properties. The isolated antioxidants of ginger may be divided into two groups; gingerol-related compounds (gingerol, shogaol, zingerone) and diarylheptanoids. Altogether, about 50 types

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of antioxidants have been identified in extracts of ginger roots. These compounds contribute to both radical scavenging effect and inhibitory effect of autoxidation of oils. Antioxidant activity of ginger is also enhanced due to its antioxidants affinity to substrates [9]. Ginger has been found to inhibit lipid peroxidation and successfully scavenge superoxide anions [10]. It was found that most of the isolated compounds exhibited stronger antioxidative effect than α-tocopherol (vitamin E) [11]. The antioxidant effect and the total phenols of ginger extract were studied by STOILOVA et al. [12]. Total phenols of the alcohol extract were found to be 870.1 $mg.g^{-1}$ dry extract. Scavenging of free 2,2-diphenyl-1-picrylhydrazyl radical (DPPH) reached 90.1% and exceeded that of the standard antioxidant, butylated hydroxytoluene (BHT). Ginger also protected tissues from the radiation damage [13]. Twenty-seven vegetables, fifteen aromatic herbs and some spices consumed in Central Italy were studied to reveal total phenolic, flavonoid and flavanol contents as well as their antioxidant capacity measured by the oxygen radical absorbance capacity (ORAC) method [14]. Among the spices tested, cumin and fresh ginger made the most significant contribution to the antioxidant capacity. The antioxidant activity of extracts from 36 vegetables was evaluated by using a model system consisting of β-carotene and linoleic acid [15]. Ginger was found to have more than 70% antioxidant activity. The antioxidant activity correlated significantly and positively with total phenolics. The addition of liquid extracts of all the herbs and spices, in particular the extracts of sage and ginger, which showed the strongest inhibition of lipid oxidation, significantly suppressed lipid oxidation of pork [16].

Gallic acid and eugenol were identified as the two major antioxidants in clove (*Eugenia carophyllata*). The amounts of gallic acid and eugenol were determined to be 1.26 g and 3.03 g respectively in 100 g of clove [17]. The antioxidant activity of water and ethanol extracts of clove buds was studied by GÜLCIN et al. [18]. The clove extracts had an effective reductive potential, as well as superoxide anion radical scavenging and metal chelating activities at all tested concentrations. The antioxidant activities of clove bud extracts and its major aroma components, eugenol and eugenyl acetate, were comparable to that of the natural antioxidant, α-tocopherol [19].

The largest systematic screening of antioxidants in dietary items, as the result of analysis of 1113 food samples including some spices, was published by HALVORSEN et al. [20]. The FRAP (ferric-reducing ability of plasma) was used to measure the concentration of total antioxidant. The food categories containing the highest antioxidant contents were spices and herbs, nuts and seeds, chocolate and sweets, vegetables and vegetable products, ready-to-eat cereals, desserts and cakes, and berries and berry products. The highest contents of antioxidants (in millimoles per 100 g) were found in dried ground cloves (126), oregano (40.3), ginger (21.6), cinnamon (17.7), turmeric powder (15.7), walnuts (13.1), basil (12.3), and in mustard seeds (10.5). Similarly DRAGLAND et al. [21] presented contents of antioxidants determined by FRAP assay, for example (in millimoles per 100 g) in clove 465.3, oregano 160, allspice 101.5, ginger 22.5, black pepper 8.7 and cumin 6.8.

Both lipophilic and hydrophilic antioxidant capacities were determined using the oxygen radical absorbance capacity ($ORAC_{FL}$) assay with more than 100 different kinds of foods including fruits, vegetables, nuts, dried fruits, spices, cereals and infant foods [22]. The hydrophilic $ORAC_{FL}$ value expressed in Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) equivalent per gram of spices was determined to be 1533 $\mu mol.g^{-1}$ for clove and 69.4 $\mu mol.g^{-1}$ for ginger, whereas lipophilic $ORAC_{FL}$ values were determined to be 1611 $\mu mol.g^{-1}$ for clove and 218.7 $\mu mol.g^{-1}$ for ginger [22]. The contents of total phenolics as mg equivalent of gallic acid per gram were determined by WU et al. [22] to be 113 $mg.g^{-1}$ for clove and 3.2 $mg.g^{-1}$ for ginger. According to some other information, the contents of total phenols were found to be in ginger in the concentration of 78 $mg.g^{-1}$ [23] and 19.2 $mg.g^{-1}$ [24], and in clove in the concentration of 57.3 $mg.g^{-1}$ [25] and 24 $mg.g^{-1}$ [26] in dependence on the extraction techniques used by the authors.

The potential antioxidant activities of water and alcoholic extracts (1:1) of spices were investigated using enzymatic lipid peroxidation inhibition [27]. Among the spices tested, clove exhibited the highest while onion showed the least antioxidant activity. The relative antioxidant activities decreased in the following order: clove, cinnamon, pepper, ginger, garlic, mint, onion. The antioxidant activities of spice extracts were retained even after boiling for 30 min at 100 °C, indicating that the spice constituents were resistant to thermal degradation.

The effect of heating on antioxidant effectiveness and the chemical composition of basil, cinnamon, clove, nutmeg, oregano and thyme essential oils was studied using scavenging of DPPH radical [28]. When heated up to 180 °C, nutmeg oil (but not the other essential oils under study) showed a significantly higher free radical-scavenging activity and evident changes in its chemical composition. Chemical composition and the related total antioxidant capacities of twelve spice essential oils were analysed by POLITEO et al. [29]. Based on their antioxidant capacity, twelve spice essential oils were sorted in the descending order: clove > basil > laurel > coriander > nutmeg > black pepper > everlast > mint > marjoram > cinnamon > sage > fennel.

Not much information is available on the effects of irradiation on the antioxidant activity of spices. The effect of irradiation on antioxidant properties of seven dessert spices (anise, cinnamon, ginger, licorice, mint, nutmeg, and vanilla) was evaluated by MURCIA et al. [30]. With respect to the non-irradiated samples, water extracts of the irradiated spices at 1, 3, 5, and 10 kGy did not show significant differences in the antioxidant activity in the radical-scavenging assays used.

Many of the spice volatile oil components have antioxidant and other bioactive properties. The volatile essential oils of commercial samples of clove, cardamom and nutmeg gamma-irradiated at 10 kGy were analysed along with their non-irradiated counterparts [31]. No qualitative and major quantitative changes were observed in the essential oil constituents of irradiated clove and cardamom. Five commercially important spices, namely cinnamon, clove, cardamom, nutmeg and mace, were subjected to gamma irradiation using a dose of 10 kGy [31]. In clove and nutmeg, quantitatively significant changes were noted in some of the phenolic acids upon irradiation. The contents of gallic and syringic acids in the irradiated clove increased by 2.2- and 4.4-fold respectively, whereas in irradiated nutmeg, many of the phenolic acids showed wide increases and decreases in the range from two to six fold compared with the control samples. In peeled ginger samples, the decrease in 6-gingerol was found to be insignificant after irradiation at a dose of 5 kGy radiation [32].

Volatile essential oils of fresh ginger rhizomes gamma-irradiated (60 Gy) for sprout inhibition and non-irradiated control rhizomes were isolated by a simultaneous distillation-extraction technique [33]. Zingiberin, β-sesquiphellandrene and ar-curcumene were the major compounds identified, with zingiberin accounting for 40% of the essential oil. A dose of 5 kGy was shown to reduce total microbial load of dry ginger to a considerable extent, while a dose of 10 KGy was shown to make the spice sterile without affecting its flavour quality [34]. On the other hand, sprouting in fresh ginger rhizomes during storage at 20 °C was arrested effectively at a much lower dose of 40 Gy [35].

Basic methods available for the measurement of antioxidant capacity in foods are well reviewed by PRIOR et al. [36] presenting the general chemistry underlying the assays, the types of molecules detected, and the most important advantages and shortcomings of each method. Scavenging of the stable radical DPPH assay is considered a valid and easy assay to evaluate scavenging activity of antioxidants, since the radical compound is stable and does not have to be generated as in other radical scavenging assays. This assay has been frequently applied to characterize antiradical activities of spice extracts. Electron paramagnetic resonance (EPR) is a very useful spectroscopic method and allows free spice radicals to be detected in dry samples. In the case of spices, the method is used mainly for detection of their irradiation. EPR was used for studying scavenging of hydroxyl radicals with a mixture of ginger, turmeric and cayenne pepper, or rosemary, sage, thyme, and oregano [37].

Oxygen consumption of linoleic acid emulsion, methyl linoleate oxidation based on thermal acceleration and induction period of lard oxidation at 100 °C (Rancimat assay) were used for evaluation of antioxidant activities of extracts from ginger, turmeric, and cayenne pepper, or a mixture of rosemary, sage, thyme, and oregano [37, 38]. Methods for testing the antiradical activity of spices were partially reviewed by SUHAJ [39].

MATERIALS AND METHODS

Materials and sample preparation

For the antioxidant activity determination of unirradiated (reference) and irradiated spices, powdered clove flower buds (*Syzygium aromaticum*) and ginger roots (*Zingiber officinale*) originating in India were used. Both raw spices harvested in 2005 were obtained from wholesale distributor Mäspoma (Dvory nad Žitavou, Slovakia) where they were ground, clove using liquid nitrogen and ginger by a hammer mill with a 1-mm sieve. The spice samples were irradiated according to commercial practices in Artim (Prague, Czech Republic) using ^{60}Co source at average doses of 5, 10, 20 and 30 kGy at dose a rate of 2 $kGy.h^{-1}$. The doses were chosen with respect to the Directive EC 1999/3 [6] as well as to FDA limits [8] for spices irradiation. Properties of the radiation-processed samples were compared to those of respective reference unirradiated (0 kGy) samples. All samples of spices were stored in polyethylene bags at laboratory conditions (25 °C, relative humidity 40%).

Extracts from individual spices were prepared by mixing 2 g spices with 50 ml 80% (v/v) aqueous methanolic solution. The mixture was shaken for 1 h at 25 °C using a laboratory shaker (Innova 2000, New Brunswick Scientific, Edison, New Jersey, USA) at 3.3 Hz and subsequently the solid phase was removed by filtration on folded paper filter 604½ (Schleicher and Schüll, Dassel, Germany).

DPPH radical-scavenging assay

DPPH radical-scavenging assay was modified according to BANDONIENÉ et al. [40] and LEBEAU et al. [41]. A volume of 0.5 ml of the methanolic ginger extract (or 0.05 ml clove extract) was added to 25 ml of the methanolic solution of DPPH and absorbance at 515 nm was measured after incubation for 5 min at 25 °C. The radical-scavenging activity was expressed as percentage and was calculated as:

$$\% = \frac{(\text{absorbance of control} - \text{absorbance of sample})}{\text{absorbance of control}} \times 100$$

Different volumes of the methanolic extracts of spices used in the scavenging assay were taken into account.

Thiobarbituric acid number

Thiobarbituric acid reactive substances (TBARS) were determined according to ZIN [42]. To 1 ml of methanolic spice extract, 2 ml of 20% trichloroacetic acid and 2 ml of 0.67% w/w thiobarbituric acid solution were added. This mixture was then placed in a boiling water bath for 10 min. After cooling, it was centrifuged at 500 *g* for 20 min. Thiobarbituric acid number was determined as the absorbance of the supernatant at 532 nm.

Reducing power

The reducing power was determined according to CHYAU et al. [43]. Spice methanolic extract (2 ml) was mixed with 2 ml of 0.2 M sodium phosphate buffer (pH 6.6) and 2 ml of 1% potassium ferricyanide, and the mixture was incubated at 50 °C for 20 min. After adding 2 ml of 10% trichloroacetic acid, the mixture was centrifuged at 200 *g* for 10 min. A volume of 1 ml from the upper layer was mixed with 1 ml distilled water and with 0.2 ml of 0.1% ferric chloride, and the absorbance was read after 1 min at 700 nm.

Total phenolic compounds

Content of total phenolic compounds was determined using the Folin-Ciocalteau reagent by a modified method [44]. A volume of 100 μl of the methanolic spice extract was diluted to 15.9 ml with distilled water, 1 ml of Folin-Ciocalteau reagent (Merck, Hohenbrunn, Germany) was added and the content was mixed. After 3 min, 3 ml of 20% sodium carbonate was added and the content was mixed. As the result of the reaction, colour was developed and absorbance at 755 nm was measured after 60 min and related to the absorbance of the blank experiment. The same procedure was repeated using a standard solution of gallic acid. The results were expressed as mg equivalents of gallic acid per 100 ml of the extract.

Spectrophotometric measurements

For the spectral measurements of DPPH radical-scavenging activity, total phenolic content, thiobarbituric acid value and the reducing power, the UV-VIS spectrophotometer Specord M40 (Carl Zeiss, Jena, Germany) was used at following conditions: spectral bandwith 10 cm^{-1}, integration time 1 s, gain 1. A square cell with a path length of 1 cm was used. Measurements were carried out at a laboratory temperature ranging from 22 to 25 °C, DPPH assay accurately at 25 °C.

Statistics

For the statistical purposes, ANOVA - Analysis of Variance (one factor) was used at a significance level of 0.05. At all determinations, three replicates of the sample were analysed.

RESULTS AND DISCUSSION

Antioxidant activity changes induced by radiation have to be correctly interpreted in relation to the dry matter contents, which may be changed during the storage of spices, and in relation to the extraction yield, which may be altered by doses of radiation [45, 46]. Irradiation degrades the membrane and the wall of cells, and so facilitates a more efficient release of the extractable substances [47]. The dry matter contents and the methanolic extraction yields of ginger and clove at different radiation doses immediately after irradiation (0 month) and after 5 months of the post-irradiation storage are shown in Tab. 1. During 5 months of storage, the dry matter contents of unirradiated (0 kGy) and irradiated ginger and clove increased by 3% or 8%, respectively, and average extraction yield increased by 22% or 2%, respectively. Radiation did not affect the dry matter contents of the spices but significantly increased the extraction yield, mainly immediately after irradiation (0 month, Tab. 1). The most pronounced increase in ginger extraction yield by 8% was observed at 30 kGy and by 5% in clove at 20 kGy. These results are in a good agreement with find-

Tab. 1. Dry matter contents and extraction yields of the irradiated ginger and clove.

	Dry matter* [% wt]		Extraction yield* [g per 100 g extract]	
	0 month	5 months	0 month	5 months
Ginger				
0 kGy	89,4 ± 0,02	91,4 ± 0,00	0,48 ± 0,02	0,60 ± 0,01
5 kGy	88,8 ± 0,05	90,8 ± 0,56	0,50 ± 0,01	0,61 ± 0,05
10 kGy	88,9 ± 0,01	92,0 ± 0,71	0,49 ± 0,05	0,63 ± 0,04
20 kGy	88,7 ± 0,02	91,6 ± 0,71	0,51 ± 0,01	0,61 ± 0,05
30 kGy	88,7 ± 0,13	90,3 ± 0,15	0,52 ± 0,01	0,61 ± 0,04
Clove				
0 kGy	81,6 ± 0,14	87,2 ± 0,92	1,28 ± 0,01	1,34 ± 0,16
5 kGy	81,5 ± 0,16	88,3 ± 1,22	1,34 ± 0,03	1,34 ± 0,14
10 kGy	81,8 ± 0,04	88,2 ± 0,74	1,30 ± 0,01	1,34 ± 0,14
20 kGy	81,6 ± 0,04	87,9 ± 1,09	1,34 ± 0,02	1,33 ± 0,11
30 kGy	81,7 ± 0,01	88,4 ± 1,35	1,33 ± 0,02	1,38 ± 0,10

* - mean ± standard deviation (n=3).

ings of KIM et al. [46] who observed an increase in the methanolic extraction yield between 5% and 25% at irradiation of more than twenty kinds of medicinal herbs at a dose of 10 kGy.

The effect of radiation on the antioxidant activity of irradiated clove and ginger measured in the methanolic extracts of these spices by the determination of free DPPH radical-scavenging activity, total contents of phenolic substances, thiobarbituric acid number and reducing power, are shown in Figs. 1–8.

Fig. 1 presents the results of antiradical activity of irradiated and unirradiated clove. The used doses of radiation did not cause any changes in

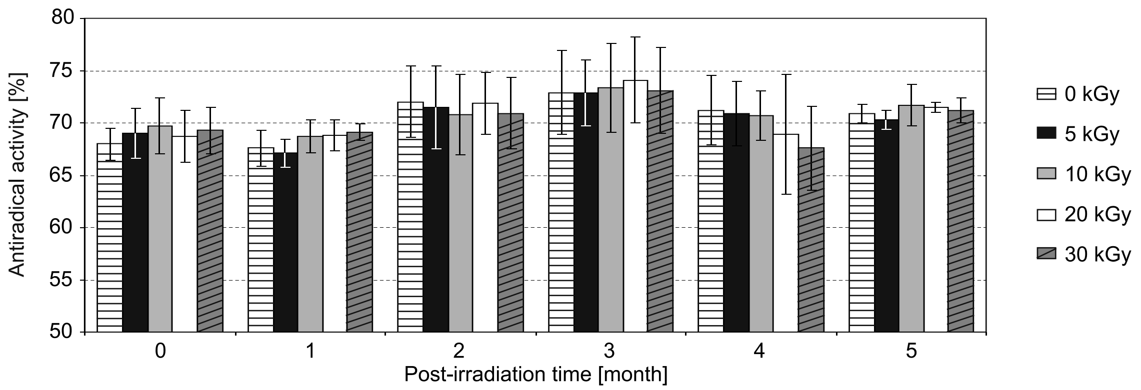

Fig. 1. Effect of irradiation on the DPPH radical-scavenging activity of clove.

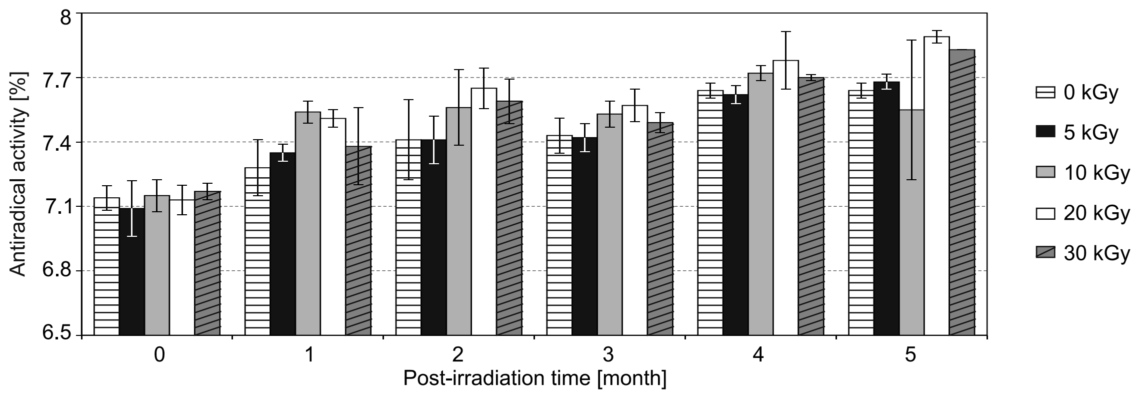

Fig. 2. Effect of irradiation on the DPPH radical-scavenging activity of ginger.

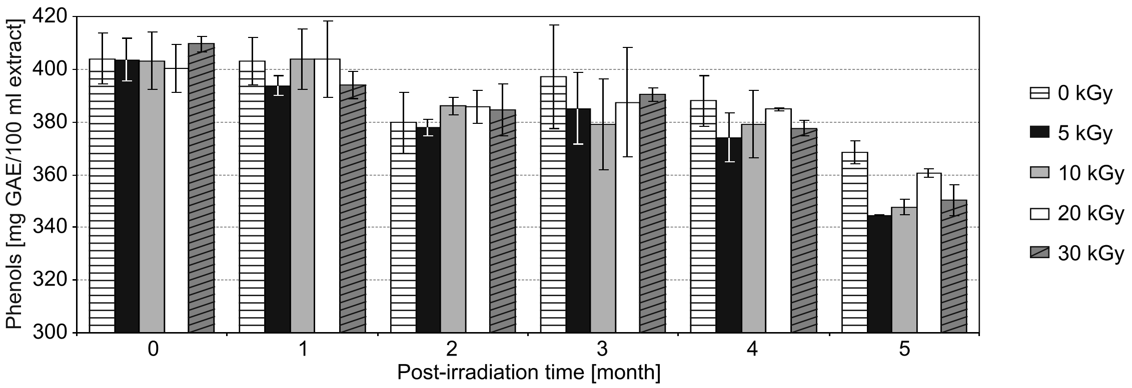

Fig. 3. Effect of irradiation on the total phenols contents of clove.

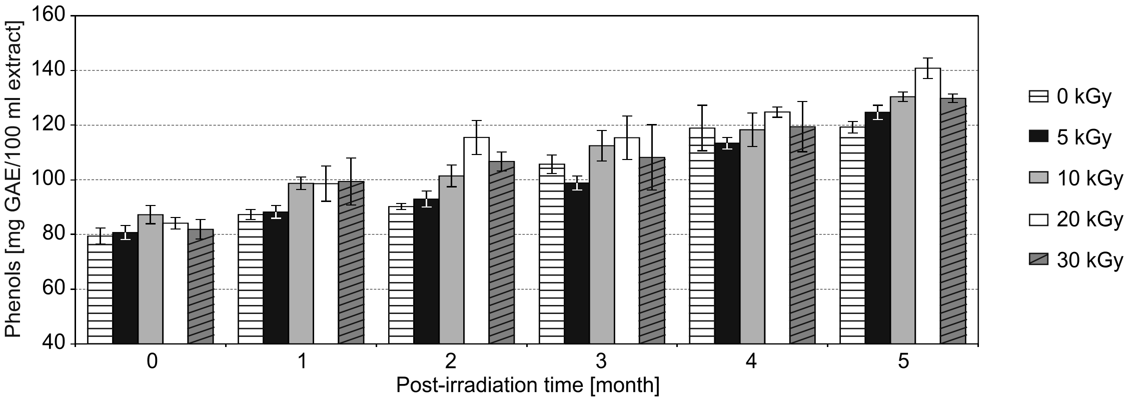

Fig. 4. Effect of irradiation on the total phenols contents of ginger.

the ability of clove methanolic extracts to quench the free DPPH radical, neither immediately after irradiation, nor during the storage of irradiated and reference clove samples. Similarly, the storage alone did not induce changes in the clove DPPH antiradical activity. Similar antiradical stability was found in dessert spices [30], in oregano [5], in medicinal herbs irradiated at 2.5 to 20 kGy [45, 48, 49], or in dry rosemary leaf powder irradiated at 30 kGy [50]. In contrast, in the case of black pepper treated with doses between 5 and 30 kGy, the scavenging activity of methanol extracts tended to decrease [1, 3].

The antiradical activity of ginger in the same conditions of the DPPH assay was approximately 10 times lower in comparison to clove (Fig. 2) but similarly, ginger methanolic extracts did not show significant modification in their scavenging activity immediately after irradiation. These results are in a good agreement with findings concerning ginger irradiation stability observed by MURCIA et al. [30]. However, during the storage of ginger, in particular at doses of 10 and 20 kGy, the antiradical activity significantly increased by 10%. This increase may be explained by an increase in the extraction yield of ginger (Tab. 1) in connection with increasing contents of total phenolic compounds due to irradiation, as discussed below (Fig. 4).

Phenolic compounds represent a substantial portion of spice antioxidants. Total contents of these components in 1 g of spices was 88–100 mg in clove and 20–30 mg in ginger. These determined contents of phenolics in both spices are comparable to the values reviewed above. The effect of clove irradiation on total phenolic compounds in the methanolic extract is shown in Fig. 3. In contradiction to the observed increase of some phenolic acids in irradiated cloves, as it was previously described by VARIYAR et al. [31], this change was not proved by our experiment. All used doses of gamma radiation applied to dry ground clove (Fig. 3) did not significantly affect the contents of total phenolic compounds in the methanolic extracts of this spice. The five months storage alone decreased the contents of phenolic substances by 8% in the reference, and by 14% in the irradiated clove. Similarly to our findings, gamma irradiation at 30 kGy had no effect on the contents of phenolic compounds for example in a dry rosemary leaf powder [50].

In opposite to clove, significant changes in the contents of total phenolic compounds were observed in ginger after irradiation, compared to the control sample Fig. 4. The highest increase in phenolics, up to 35%, was observed at a dose of 20 kGy after the second month of ginger storage. The increased contents of phenolic compounds in the methanolic extracts of irradiated ginger can be explained not only by a better extractability of the irradiated spices [47] but in addition, according to ADAMO et al. [51], by the fact that the destructive process of oxidation and gamma irradiation are capable of breaking chemical bounds of polyphenols and thereby releasing soluble phenols of a low molecular weight. The increase in soluble phenols in some foods after irradiation was confirmed for example in oregano by HORVÁTHOVÁ et al. [5], in spices by VARIYAR et al. [31, 52], in cabbage by AHN et al. [53], in vegetable juices by SONG et al. [54], and in mushrooms by HUANG and MAU [45]. Storage alone caused a more significant increase in phenolics than irradiation in the reference as well as in the irradiated ginger. In the case of unirradiated ginger, increase after 5 months of storage achieved 50% and was up to 67% at a dose of 20 kGy.

The effect of irradiation and storage on the contents of oxidative products determined as TBARS values in methanolic extracts of clove and ginger is shown in Fig. 5 and Fig. 6. TBARS values of non-irradiated control samples of these spices were lower than those of the irradiated ones. The increase in these values was dose-dependent and the greatest differences were found immediately after irradiation at 20 kGy and reached 30% at clove and 35% at ginger. Similar increase in this value was observed with methanolic extracts of black pepper and oregano irradiated by doses between 5 and 30 kGy [1, 5]. Post-irradiation storage caused a progressive loss of dose-dependent differences in TBARS values at both spices. Storage alone in the case of clove caused a decrease in TBARS values (approximately by 18% at 20 and 30 kGy). The changes in TBARS values at ginger

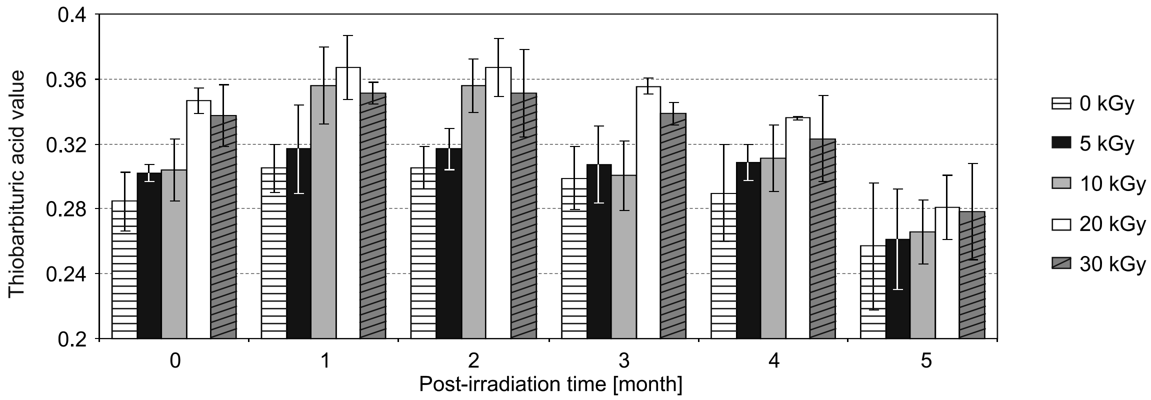

Fig. 5. Effect of irradiation on the thiobarbituric acid number of clove.

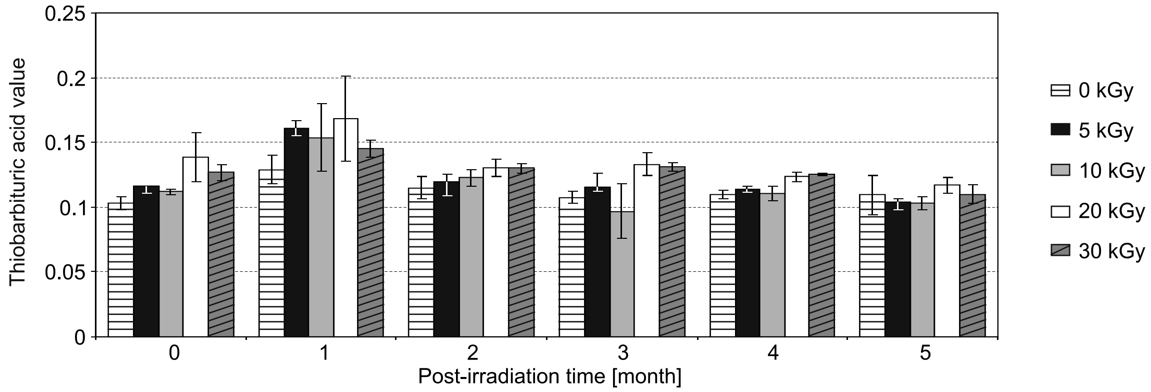

Fig. 6. Effect of irradiation on the thiobarbituric acid number of ginger.

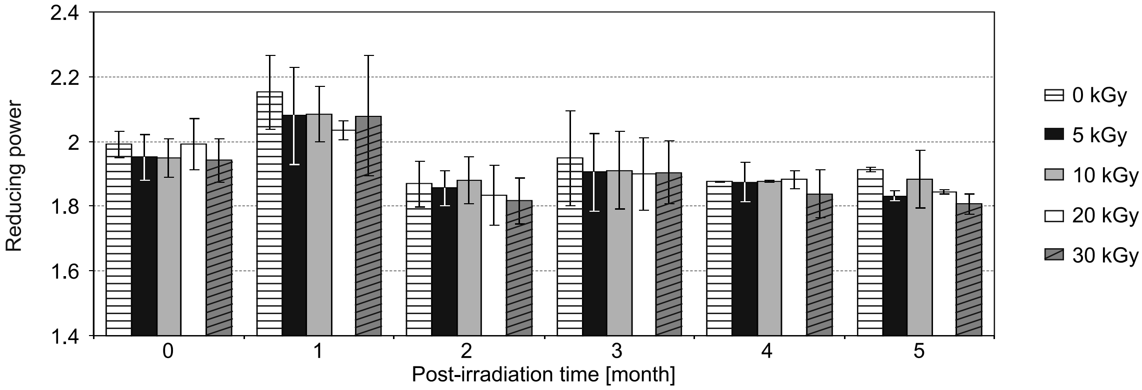

Fig. 7. Effect of irradiation on the reducing power of clove.

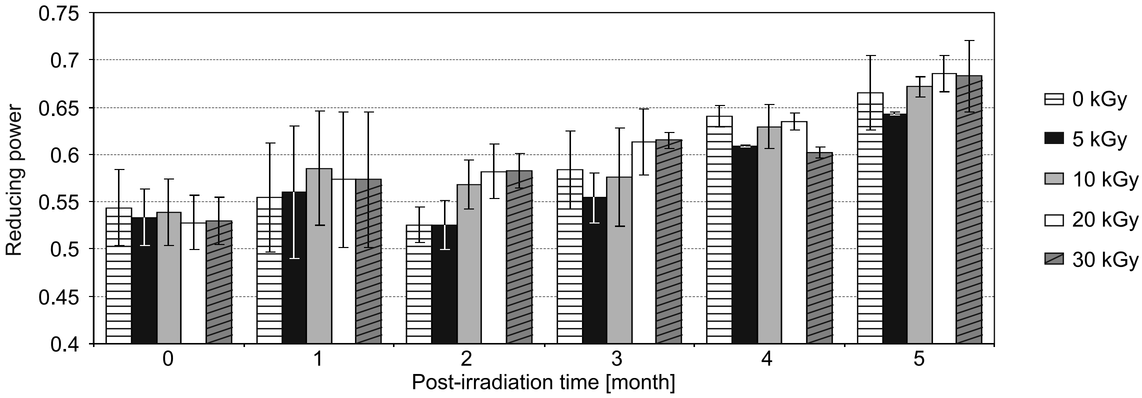

Fig. 8. Effect of irradiation on the reducing power of ginger.

were insignificant with the exception of the first month of storage.

The used doses of gamma radiation did not affect the reducing power of methanolic extracts of the irradiated clove and ginger (Fig. 7 and Fig. 8). Some similar results were previously observed for example at oregano irradiated by 30 kGy [5], at a powdered ginseng irradiated by 10 kGy [48], or in a dry rosemary leaf powder irradiated by 30 kGy [50]. In contrast, irradiation between 5 and 30 kGy lead to a decrease in the reducing power of black pepper [1]. Post-irradiation storage alone of the reference and the irradiated clove lead to a weak (5%) decrease in the reducing power, contrary to the increase in the dry matter contents (by 8%) (Tab. 1). The storage alone of the irradiated and non-irradiated ginger increased the reducing power of the methanolic extracts by 22%.

It should be noted here that in this study, only one source of commercially-available spice samples was analysed and, therefore, the conclusions presented are to be related just for this occasion. The information about the pre-irradiation history, way of processing, potential pre-treatment or storage conditions during the harvest, transport and distribution were unavailable to us and thus could not be taken into account.

An additional study should deal with the comparison of antioxidant properties of gamma-irradiated ginger and clove varieties originating from different producing regions and/or producers and/or harvested in different seasons and/or pre-treated in different ways (e.g. heat-treated, UV-irradiated, etc.), in order to verify the effects of these factors on the total antioxidant status of spices.

CONCLUSIONS

Taking into account the changes in the dry matter contents and in the extraction yields of both spices, and the results of the antioxidant activity testing, it can be seen that namely clove shows strong antioxidant properties, which protect this spice in the conditions of irradiation treatment at legal doses of radiation. Storage alone of clove and ginger caused more intensive changes of the antioxidant properties than the irradiation. The increased extraction yields induced by radiation influenced the antioxidant activity of these spices namely in ginger during the post-irradiation storage period. Correlation between the results of individual methods for the determination of the antioxidant activity was low, a relatively higher correlation was observed only between the DPPH radical-scavenging activity and the contents of phenolic compounds.

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