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ORIGINAL RESEARCH PAPER

THE COMPARATIVE EFFECT OF HEATING AND IRRADIATION ON THE PHYSICOCHEMICAL AND SENSORY PROPERTIES OF LICORICE ROOTS POWDERS (GLYCYRRHIZA GLABRA L.)

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A study was conducted to investigate the changes in the physicochemical and sensory properties of the licorice root powders extracts as a function of heating, steaming, gamma irradiation and storage periods. Physical and chemical analyses of the extracts were performed after 0 and 12 months of storage, whereas, sensory evaluation was done only two days after irradiation. The results showed that the extraction yield of licorice root measured as organic dissolved solids was significantly increased by heating and decreased by steaming, but there was no significant difference between irradiated and non-irradiated samples. Reduced sugar, glycyrrhizin components, pH values, and color of the extracts were found to be decreased due to heating and steaming. Also the heating and steaming increased the total sugar and viscosity of the licorice root extracts. No differences were verified in the overall sensorial (color, flavor, texture, and taste), physical (color and viscosity), and chemical (total sugar, reduced sugar, glycyrrhizin components, and pH values) properties of licorice root extracts after irradiation with 10 kGy.

Keywords: licorice, irradiation, heating, extraction yield, sensory evaluation, physicochemical properties

Introduction

The use of herbs and spices to improve health has a long history including traditional and cultural aspects (Tapsell *et al.*, 2006). However, microbiological contamination of herbs that could occur either during pre or post-harvest processing is of a serious concern (Soriani et al., 2005). Some methods are used for microbial decontamination of herbs and spices including fumigation, heating and irradiation (Tapsell *et al.*, 2006; Kumar *et al.*, 2010; Soriani *et al.*, 2005). However fumigation with gaseous ethylene oxide or methyl bromide is prohibited or increasingly restricted in many countries because of associated health hazards (Shim *et al.*, 2009). The application of high-temperature steam is associated with color degradation, a decrease in volatile oil content, and an increase in moisture content of the herbs and spices which leads to a decreased shelf-life (Almela *et al*., 2002; Lilie *et al*., 2007).

Irradiation decontamination of herbs and spice is currently the most popular application in food irradiation because their aromatic quality is well maintained after irradiation (Kim *et al*., 2009). Some chemical and physical changes are induced in food herbs and spices as a result of irradiation (Salum *et al*., 2009; Kim *et al*., 2008; Byun *et al*., 2008).

Licorice (*Glycyrrhiza glabra*) root is used worldwide as a natural sweetener, as well as flavoring additive in various cases (Shibata, 2000). Since licorice roots have been widely used for a variety of purposes, the chemical constituents were the subjects of many investigations (Kitagawa, 2002; Khattak and Simpson, 2010). Licorice roots are commercially distributed in both unprocessed raw roots and processed forms, and irradiated products (Al-Bachir and Lahham, 2003, Al-Bachir and Zeinou, 2005; Al-Bachir *et al*., 2004). There is no information available in the literature on the effect of steaming and dried heating on the extraction yield and its characteristics of licorice root powders. Therefore, the objective of this study was to assess the impact of gamma radiation, dried heat treatments, and steaming on the changes in sensory, chemical and physical characteristics of the licorice root powder extracts.

Materials and Methods

Licorice root powders preparation

Roots of *Glycyrrhiza glabra* L. were harvested in August 2010 from an orchard located in eastern Syria (Raqqa). Roots were dried under sun and then crushed by millstones and stored at ambient temperature at a local factory. In February 2011, a total of 1000 g of root powders was packed in polyethylene plastic bags, labeled and identified with respective radiation, steaming, and heating.

Treatment and storage

Whole packed licorice root powders were divided into four lots. One lot was treated with dried hot air treatment (H) at 60°C for 24 hr using dried blender (WTC. Binder, Type, FE, 115, 7200 Tulttlingen, Germany). The second lot was steamed (S) at 1.1 bar and about 121°C for 15 min using steam sterilizer (Varioklav, Dampfsterilisator, Type EH 500, Munich, Germany). The third lot was irradiated at 10 kGy using a ^{60}Co source with a dose rate of 719 Gy/ h at room temperature. The absorbed dose was determined using alcoholic chlorobenzene dosimeter by the measurement of chloride ions or hydrogen ions by means of the Oscillotitrator (OK-302/2, Radelkisz, Budapest, Hungary). The forth lot was served as control (C). After treatments, root powders were stored for 12 months at room temperature 18 to 25°C under a relative humidity (RH) of 50 to 70%. Extraction and physicochemical analyses of suspension extracted from controls and treated samples were performed immediately after treating, and after 12 months of storage. Sensory evaluation was done only two days after treating.

Extraction yield

To obtain licorice extracts from the commercially root powder, 20 ml of distilled water were added to each sample of 5 g from each treatment and mixed for 20 minutes. The suspension was made up to 200 ml with hot distilled water (75°C) and mixed for 3 h (Al-Bachir and Lahham, 2003). Total dissolved solids (by drying the extract for 6 h at 105°C) were determined in the extracts according to the standard methods (AOAC, 2010).

Chemical analysis

The pH values of the licorice root extracts at 28°C were determined using an HI 8521 pH meter (Hanna Instruments, Woonsocket, RI, USA). Glycyrrhizin components were determined on Milton Roy 1201 spectrophotometer at wave length of 258 nm (Al-Bachir and Lahham, 2003).

Total sugar was estimated using Anthrone indicator method by measuring the absorbance at 620 nm with a T70 UV/VIS Spectrophotometer, (PG Instrument Ltd). The reducing sugars were estimated by iodometric determination of the unreduced copper remaining after reaction, and the concentration of reducing sugars were expressed as g glucose/ 100 g powders (AOAC, 2010).

Physical analysis

To determine viscosity change, the water extracts of commercially powder of licorice roots was prepared according to methods of Hayashi (1996). The viscosity of the extracts was measured with HAAKE viscometer 6 R plus Model (RTM) using a R2 column at 200 rpm. Viscosity values were determined and expressed as mPa/s.

The color of licorice root extract was measured using AvaSpec Spectrometer Version 1, 2 June 2003 (Avantes, Holland) at wave length of 670 nm by exposing the samples to the illuminant A light source and the CIE L (lightness), a (redness), and b (yellowness) values were obtained (Kwon et al., 2009).

Sensory evaluation

For the sensory evaluation, 25 ml of licorice root extracts were placed in a numerically coded weight glass beaker. A sensory test (using a consumer-type panel, comprised of 25 persons) was employed to detect sensory linking differences between treated and non-treated samples. Each member independently evaluated a licorice root extract for texture, color, and aroma on a 5 point scale (1: extremely poor, 2: poor, 3: acceptable, 4: good 5: excellent), according to Al-Bachir and Lahham, (2003).

Statistical analysis

The four treatments and two storage periods were distributed in a completely randomized design with three replicates. Data were subjected to the analysis of variance test (ANOVA) using the SUPERANOVA computer package (Abacus Concepts Inc, Berkeley, CA, USA; 1998). A separation test on treatment means was conducted using Fisher's least significant differences (LSD) methods (Snedecor and Cochran, 1988) at 95% confidence level.

Results and discussion

Extraction yield

The extraction yield of licorice root powders in water was determined and is shown in Table 1. The non-treated water extracts of licorice root powders showed 15.15% dry weight yield (total dissolved solids). This is in disagreement with the earlier results reported by Al-Bachir and Lahham (2003), Al-Bachir and Zeinou, (2005), and Khattak and Simpson, (2010), who showed remarkable differences in the extraction yields. They reported that the extraction yields ranged from 22.8 to 31.5 for the water extract of licorice root powders collected from various sites in Syria and Pakistan. The difference in the decrease in extraction yields, as compared to that reported in the literature may be due to different chemical composition of plants.

Radiation treatment resulted in a slight increase in the extraction yields of licorice root powders (15.92%). The increase in extraction yields with radiation treatment has also been reported by Khattak *et al*. (2008), Hung and Mau (2007), Kim *et al.* (2000), Al-Bachir and Zeinou (2005) found an increase in the extraction yields after treating medicinal herbs with gamma irradiation. Also, the dried heat treatment increased significantly the extraction yields (18.11%) of licorice root powders, but the steaming decreased the extraction yields (13.88%). The increase in the dry weights of extracts following irradiation or dried heating might be due to degradation of some high molecular weight components, and changing these components from non-soluble to soluble ones in the test solvents (Khattak *et al*., 2008).

The extractable yield, on the other hand, increased considerably in all the samples after storage. This could be attributed to the increase of dry matter content during storage and polysaccharide de-polymerization of the plant (Rico *et al.*, 2010).

Physiochemical analysis

To characterize the biochemical characteristics of licorice root powder extracts, parameters such as, glycyrrhizin components, total sugar, and reducing sugar were analyzed whereas, for physical nature of the extracts, pH, color intensity, and viscosity were studied.

Glycyrrhizin components

Table 1 summarizes the changes in the level of glycyrrhizin components of the water extracts of licorice root powders due to irradiation, steaming, heating, and storage periods. The concentration of glycyrrhizin components in water extract produced from non-treated licorice root powders was 3.88%. In general, the concentration of glycyrrhizin in fresh root of licorice ranged from 3 to 5% (Isbrucker and Burdock, 2006). Therefore, our results are in agreement with previous references. Irradiated (3.91%) and non-irradiated (3.88%) licorice root powders showed the same behavior. Steamed (3.37%) and heated (3.46%) samples showed a decreased in the glycyrrhizin components. The glycyrrhizin components decreased in all samples throughout storage periods. After 12 months of storage, the concentration of glycyrrhizin components were 2.57%, 2.58%, 2.56%, and 2.58% in extracts of control, irradiated, steamed, and heated samples, respectively

(Table 1). Though various researchers have worked on the glycyrrhizin components evaluation of the licorice root powders and the effect or gamma irradiation on its extracts (Al-Bachir and Lahham, 2003; Al-Bachir and Zeinou, 2005; Khattak and Simpson, 2010). Nothing is reported on the effect of steaming or dried heating on the glycyrrhizin components of the licorice root powders. However some researchers studies showed different results for the effect of steaming and heating on the functional compounds and antioxidant properties of plant materials. A research study conducted by Rico et al. (2010) indicated that the functional components of spices were not apparently affected by steaming, and steamed red pepper exhibited high 1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activity even after 6 months of storage. On the other hand, Jeo *et al.* (2009) reported that the antioxidant activities determined by DPPH and hydroxyl radical scavenging activities were decreased in heated and steamed garlic.

Table 1. Effect of gamma irradiation and heat treatment on total dissolved solid (%) glycyrrhizin components (g/100g) extracted from licorice root powder stored at room temperature (10 … 15 ^{o}C).

Storage period (months)	**0**	**12**	**LSD 5%**
Treatments Total dissolved solid (%)			
C	15.15±1.38	27.00±1.03	2.76
I	15.92±0.30	28.72±3.37	5.42
S	13.88±0.71	28.37±3.71	6.05
H	18.11±0.68	31.88±0.95	1.88
LSD 5%	**1.62**	**4.90**	
Glycyrrhizin components (g/100g)			
C	3.88±0.37	2.57±0.01	0.59
I	3.91±0.14	2.58±0.03	0.23
S	3.37±0.26	2.56±0.01	0.42
H	3.46±0.18	2.58±0.01	0.29
LSD 5%	**0.47**	**0.03**	

C: (Control); I: (Irradiation); S: (Steam treatment); H: (Hot air treatment).

Sugar contents

Table 2 shows that the concentration of total and reducing sugar in water extract produced from non-treated licorice root powders was 6.95% and 4.65%, respectively. Irradiation, steaming and heating increased the total sugar and decreased the reducing sugar. After 12 months of storage, the total and reducing sugar content increased in all samples regardless of the treatments. These increments for reducing sugar were higher in steamed and heated samples than irradiated and non-irradiated ones. This could be due to non-enzymatic browning reaction, involving reducing sugar that occurred as a result of steam, dried heat, and radiation processing of licorice root powders. Previous researches have shown that thermal or irradiation treatment and prolonged storage of food containing substantial amount of reducing sugars and amino acids could cause non-enzymatic browning reactions (Chawla *et al.*, 2009; Gogus and Eren, 1998), resulting in the darkening of food and decreased amount of reducing sugars. Previous studies conducted by Rico et al. (2010) revealed a decrease in reducing sugar content of irradiated and non-irradiated red pepper during storage.

Table 2. Effect of gamma irradiation and heat treatment on carbohydrate (%) extracted from licorice root powder stored at room temperature (10… 15 °C).

Storage period (months)	0	12	LSD 5%
Treatments Total sugar (%)			
C	6.95±0.08	7.25±0.46	**0.75**
I	7.97±0.15	7.45±0.14	**0.34**
S	7.13±0.05	8.35±0.13	**0.23**
H	7.98±0.24	8.74±0.47	**0.84**
LSD 5%	**0.29**	**0.64**	
Reduced sugar (%)			
C	4.65±0.03	4.82±0.56	**0.90**
I	4.47±0.04	5.59±0.85	**1.36**
S	2.64±0.04	4.86±0.02	**0.07**
H	2.81±0.04	4.23±0.62	**1.00**
LSD 5%	**0.07**	**1.12**	

C: (Control); I: (Irradiation); S: (Steam treatment); H: (Hot air treatment).

pH value

The pH values of the water extracts produced from irradiated, steamed, heated, and non-treated samples of licorice roots are given in Table 3. The pH value of extracts produced from non-treated licorice root powder was 8.57±0.07. Steaming and irradiation treatments did not significantly affect the pH of the extracted licorice root samples, after 0 and 12 months of storage, but the values slightly decreased immediately after treatments, and increased after 12 months of storage due to dried heating. It was also noted that the pH was decreased in control, irradiated and steamed samples stored for 12 months at room temperature. These results are in agreement with the report Rico *et al.* (2010) who found that steaming and irradiation treatment did not significantly affect the pH value of dried red pepper, but values slightly decreased after storage. The decrease in pH during storage was probably due to an increased amount of organic acids released during storage, irradiation and steam treatments

Viscosity

The effects of gamma irradiation, steaming, and dried heating on relative viscosity of licorice root extracts are shown in Table 3. It can be seen that, immediately after processing, irradiation had no effect on viscosity (19.00 mPa·S), but steaming (20.67 mPa·S) and dried heating (22.00 mP·S) increased significantly the viscosity of licorice root extracts as compared with control (19.33 mPa·S). However, after 12 months of storage, no significant differences were seen among extracts prepared from un-treated, irradiated, steamed, dried heated licorice root powders. The previous studies in our lab indicated that, immediately after irradiation, 5, 10, 15, and 20 kGy of gamma irradiation doses decreased significantly the viscosity of licorice extracts as compared with control. However, after 12 months of storage, no significant differences were seen among extracts prepared from irradiated and un-irradiated licorice roots (Al-Bachir and Lahham, 2003). The differences in the viscosity between extracts produced from heated and non-heated commercially ground licorice roots (immediately after heating) may be attributed to the degradation of some high molecular weight components, and changing these components from non-soluble to soluble ones in the test solvents. The increment of the dissolved solid in the solvent (Table 1) could lead to increasing the viscosity. However, by lowering molecular weight of polysaccharides, they are likely to be depleted of some important properties and it does not compromise the rheological properties of the polymers. Shortening of the polysaccharide macromolecular chains can be achieved by various methods such as ultrasound, microwave heating and ionizing irradiation (Byun *et al.*, 2008; Kim *et al.*, 2008).

Table 3. Effect of gamma irradiation and heat treatment on acidity (pH value) and viscosity (mPa·s) of extracted licorice root powder stored at room temperature (10… 15 °C).

Storage period (months)	0	12	LSD 5%
Treatments PH Value			
C	8.57±0.07	8.03±0.19	**0.32**
I	8.63±0.04	7.82±0.08	**0.14**
S	8.49±0.03	7.97±0.20	**0.23**
H	8.44±0.02	8.49±0.05	**0.08**
LSD 5%	**0.08**	**0.27**	
	Viscosity (mPa·s)		
C	19.33±0.58	16.00±0.00	**0.93**
I	19.00±1.00	16.00±0.00	**1.60**
S	20.67±0.58	16.00±0.00	**0.93**
H	22.00±0.00	16.33±0.58	**0.93**
LSD 5%	**1.22**	**0.54**	

C: (Control); I: (Irradiation); S: (Steam treatment); H: (Hot air treatment).

Color intensity

Color parameters of irradiated, heated and steamed licorice root extracts such as lightness (L*-value), redness (a*-value), yellowness (b*-value), and color difference (delta E), were determined (Table 4). Gamma irradiation had no effect on the lightness (L*-value), and redness (a*-value), but the yellowness (b-value) was less intense of licorice root powder extract.

The water extracts prepared from steamed, and dried heated licorice root powders became darker (L-value) and yellowness (b-value) was less intense. After storage, the color values of all samples increased. The L- and a- value of extracts produced from irradiated licorice root powders significantly increased after storage, but the b-values were not affected compared to those of control. The L- and a- value of steamed and heated licorice root powder extracts increased after storage, but the b-values were significantly decreased compared to those of control.

There is no information available in the literature on the effect of steaming and dried heating on the Hunter's color values of licorice root powders. However, for other plant materials, and in studying the effect of thermal treatment on the color properties of paprika, Almela *et al*. (2002) noted that high-temperature promotes color degradation as the paprika became darker and the intensities of reddish and yellowish hues became decreased. Jeo *et al.* (2010) found that Hunter color L-value of heated garlic was significantly decreased, compared to that of control, whereas a-value and b-value were increased. Waje *et al.* (2008) also reported that steaming treatment of black pepper resulted in the darkening of the spices.

Irradiation affected the colors of the brush by reducing its brightness and increasing redness and yellowness of the herbal cosmetic products (Neramitmansook et al., 2012).

Table 4. Effect of gamma irradiation and heat treatment on color of extracted licorice root powder stored at room temperature (10… 15°C)

Storage period (months)	0	12	LSD 5%
Treatments L			
C	23.97±1.07	41.52±0.54	**1.93**
I	23.93±0.33	43.68±0.24	**0.66**
S	19.70±0.25	42.38±0.60	**1.04**
H	19.01±0.10	48.63±0.45	**0.74**
LSD 5%	**1.09**	**0.90**	
a			
C	43.51±0.61	44.50±0.25	**1.05**
I	42.26±0.75	44.84±0.08	**1.21**
S	43.56±0.90	44.67±0.08	**1.45**
H	43.57±1.69	45.00±0.08	**2.71**
LSD 5%	**2.01**	**0.27**	
b			
C	11.46±0.69	17.86±0.34	**1.42**
I	7.41±1.46	17.44±0.88	**2.73**
S	11.26±2.27	16.68±0.98	**3.96**
H	8.95±2.79	15.75±0.34	**4.50**
LSD 5%	**3.70**	**1.31**	
ΔE			
C	19.37±0.86	14.16±0.03	**1.38**
I	22.63±1.37	15.92±0.71	**2.46**
S	21.95±1.49	15.56±1.00	**2.88**
H	24.14±2.38	20.50±0.49	**3.89**
LSD 5%	**3.05**	**1.24**	

C: (Control); I: (Irradiation); S: (Steam treatment); H: (Hot air treatment).

Sensory properties

Table 5 shows the results of sensory evaluation of the extract of licorice root powders. The texture, color, and aroma of the licorice root extract were not significantly affected by irradiation, steaming, or dried heating. Our previous findings on the sensory properties of licorice root powders (Al-Bachir and Lahham, 2003; Al-Bachir and Zeinou, 2005), and licorice root products (Al-Bachir *et al.*, 2004) indicated that gamma irradiation with doses of 5, 10, 15, and 20 kGy had no significant effect in taste, flavor, color, and texture of licorice root extracts. The scientific knowledge of chemical compounds is responsible for characteristics odor and flavor of herbs and spices, which justify the food quality. Considerable efforts have been made to determine the irradiation effects on food components (Diehl, 2002).

Table 5. Effect of gamma irradiation and heat treatment on the sensory properties of extracted licorice root powder (5 point scale) stored at room temperature (10… 15^{o}C).

Treatments	Texture	Color	Aroma
C	3.52±.1.03	3.81±0.87	3.29±1.15
I	3.62±.0.74	3.95±0.81	3.62±1.28
S	3.91±1.00	4.00±0.89	3.52±1.17
H	3.86±0.79	3.38±1.12	3.52±0.87
S+H	3.62±0.81	3.81±0.68	3.14±1.11
LSD 5%	**0.56**	**0.57**	**0.69**

C: (Control); I: (Irradiation); S: (Steam treatment); H: (Hot air treatment); (S+H): (Steam treated +Hot air treatment).
[1] Data represent a 5 point scale ranging from 1 (very bad) to 5 (very good).
0.05 significant level
n = 25 person

Conclusions

The results of this work showed that heating and steaming caused color change and lower reduction of sugar, glysyrryzin components, and pH values, but higher total sugar and viscosity of licorice root extract.

The applied dose (10 kGy) of gamma irradiation did not cause any significant changes in the physico-chemical and sensory qualities of the licorice root powders. This study therefore supports the use of gamma radiation as a phytosanitary treatment for Glycyrrhiza glabra L and calls for further investigations to elucidate its effect on the other biological activities and constituents of the plant.

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