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Some chemical characteristics and volatile compound profiles of wild foxtail lily (*Eremurus spectabilis)*

Yabani çiriş otunun (Eremurus spectabilis) bazı kimyasal özellikleri ve uçucu bileşik kompozisyonu

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ABSTRACT

The wild Foxtail lily (*Eremurus spectabilis*) is a valuable vegetable consumed in different forms as food and employed as a remedy for preventive and curative purposes. In the present study, the physicochemical and antioxidant properties and the volatile compounds of the leaves and stem parts of wild Foxtail lily were determined. The moisture content, ash, pH, crude fibre, crude protein and crude fat were determined as 93.90% and 90.90%; 0.48% and 0.70%; 5.01 and 5.01; 0.62% and 1.06%; 1.4% and 2.27%; and 0.60% and 0.60% in stem and leaf, respectively. *L**, *a** and *b** values were found to be 67.77 and 46.70; -8.99 and -12.85; and 22.54 and 17.48 in stem and leaf, respectively. The total phenolic content, FRAP and DPPH were found in stem and leaf as 897.75 and 1781.83 mg GAE kg^{-1}; 5.26 and 12.29 mmol ISE g^{-1}; and 40.81 and 89.55 mmol TE g^{-1}, respectively. 11 volatile compounds were detected in Foxtail lily stem and leaf, including 3 aldehydes, 3 alcohols, 1 ester, 1 furan, 1 sulfur compound, 1 nitrogen compound and 1 aliphatic hydrocarbon. Acetaldehyde, dimethyl sulfide, methyl isocyanide and ethyl alcohol were the most important volatile compounds detected in the headspace of Foxtail lily. The leaf part presented the highest physico-chemical and antioxidant properties, while the headspace of stem provided the highest volatile compounds.

Key Words: Foxtail lily, antioxidant activity, volatile compounds, HS-SPME/GC-MS

ÖZ

Yabani çiriş otu (*Eremurus spectabilis*) farklı şekillerde gıda olarak tüketilen, koruyucu ve tedavi edici amaçlarla ilaç olarak kullanılan değerli bir sebzedir. Bu çalışmada, çiriş otunun yaprak ve sap kısımlarının fiziko-kimyasal ve antioksidan özelliklerinin yanı sıra uçucu bileşikleri de belirlenmiştir. Gövde ve yaprakta nem, kül, pH, ham lif, ham protein ve ham yağ içeriği sırasıyla %93.90 ve %90.90; %0.48 ve %0.70; 5.01 ve 5.01; %0.62 ve %1.06; %1.4 ve %2.27; ve %0.60 ve %0.60 olarak belirlenmiştir. L*, a* ve b* değerleri ise gövde ve yaprakta sırasıyla 67.77 ve 46.70; -8.99 ve -12.85; 22.54 ve 17.48 olarak bulunmuştur. Toplam fenolik madde, FRAP ve DPPH değerleri gövde ve yaprakta sırasıyla 897.75 ve 1781.83 mg GAE kg^{-1}; 5.26 ve 12.29 mmol ISE g^{-1}; 40.81 ve 89.55 mmol TE g^{-1} olarak bulunmuştur. Çiriş otunun gövde ve yaprağında 3 aldehit, 3 alkol, 1 ester, 1 furan, 1 kükürtlü bileşik, 1 azotlu bileşik ve 1 alifatik hidrokarbon olmak üzere 11 uçucu bileşik tespit edilmiştir. Asetaldehit, dimetil sülfür, metil izosiyanür ve etil alkol çiriş otunda tespit edilen en önemli uçucu bileşiklerdir. Yaprak kısmının antioksidanlarca, gövde kısmının uçucu bileşikler açısından daha zengin olduğu saptanmıştır.

Anahtar Kelimeler: Çiriş, antioksidan aktivite, uçucu bileşikler, HS-SPME/GC-MS

Introduction

Plants which are edible or not edible contain different bioactive compounds (Karakaya et al., 2017). Foxtail lily (Çiriş) *Eremurus spectabilis* Syn. *Asphodelus aestivus* or *Asphodelus microcarpus* is in the Liliaceae family. It grows in South Asia and Central Asia, including Iran, West Pakistan, Afghanistan, Iraq, Turkey, Palestine, Lebanon, Syria and the Caucasus. (Pourfarzad et al., 2014). It is a perennial herb that is about 1 meter tall with linearly large leaves (length 20-60 cm and width 4.5 cm) and long root (10-20 cm). *E. spectabilis* is widely distributed throughout the provinces of Turkey, such as Erzurum, Sivas, Yozgat, Bitlis, Usak, Kars, Agri, Erzincan, Van, Artvin and Ardahan (Aysu and Demirbas, 2014). *E. spectabilis* is locally called as "Çiris, Çireş, Dağ pırasası, Gülük, Kiriş, Sarı çiriş, Sarı zambak, Yabani pırasa" in Turkey (Tosun et al., 2012).

People living in Eastern Anatolia mostly get inadequate yields from agricultural products due to unfavorable climatic conditions and high altitudes. People in this area often use wild plants as a supplement to their general diet (Tosun et al., 2012). *E. spectabilis* is collected from nature and the young shoots and fresh leaves are cooked and consumed as vegetables. The root, blooming stem and seeds are used in various diets. It can be combined with purslane and spinach to give a prized taste. It is cooked similarly to cooking spinach by adding bulgur or sauteed with eggs, and eaten. It is also used as an ingredient for cheese making. E. *spectabilis* is traditionally used in folk medicine as antidysuria and antihypertensive as well as to treat some ailments including hemorrhoids, and diabetes, and skin problems like eczema, fungal infections (Li et al., 2000; Mamedov et al., 2008; Tosun et al., 2012; Cinar et al., 2017; Basiri et al., 2022). Also, some Eremurus species have commercial value as ornamental plants (Hadizadeh et al., 2020).

The root, leaf and stem are rich in nutrients and bioactive compounds including protein, vitamin C, β-carotene, K, Ca, Mg, Fe, Cu, Zn, methyl linolenate, chrysophanol, β-sitosterol, isoorientin, inosine and sucrose (Tosun et al., 2012; Cinar et al., 2017; Karakaya et al., 2017). Foxtail lily has been reported to contain prebiotics such as fructans and bianthraquinone glycosides which exert tremendous nutritional and pharmaceutical applications (Li et al., 2000; Pourfarzad et al., 2014; Pourfarzad and Najafi, 2015; Beigi and Jahanbin, 2019;). It has shown antioxidant, antimicrobial and gastroprotective properties (Karaman et al., 2011; Tosun et al., 2012; Kanaani and Sani, 2015; Karaoğlan et al., 2018). Moreover, previous studies have revealed the effectiveness of Foxtail lily in prevention and treatment of cancer (Tuzcu et al., 2017). In addition, carvone, carvacrol, 2-methyl-pentane, (E)-caryophyllene, valencene and cis-calamenene were detected as major volatile compounds in Foxtail lily (Karaman et al., 2011), while 4-methyl-3-penten-2-one, 4-hydroxy-4-methyl-2-pentanone, trimethyl benzene, 2,6-dimethyl-2,5-heptadien-4-one, 3-Acetyl-2,5-dimethyl furan and 3-(3-methyl-2-butenyl)-1H-indole were detected as major volatile compounds in Foxtail lily bio-oils (Aysu and Demirbas, 2014).

Thanks to health benefits and nutritional properties, *E. spectabilis* is a valuble edible vegetable. Hence, the main purpose of the present study was to investigate the volatile composition, nutritive value, antioxidant activity of *E. spectabilis* which is naturally grown.

Material and Methods

Plant material

Fresh Foxtail lily samples were purchased from eight different local markets in Erzurum province. After the plants were washed and the inedible parts were removed, each samples were seperated into stem and leaves.

Chemical and reagents

Distilled water was obtained by means of ultra pure water system (Millipore-Q). Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), diethyl ether, TPTZ (2,4,6-tripyridyl-s-triazine), DPPH (2,2-diphenyl-1-picrylhydrazyl), sulfuric acid, Folin-Ciocalteau phenol reagent,

methanol, sodium hydroxide and gallic acid were acquired from Sigma-Aldrich. Glacial acetic acid, hydrochloric acid, sodium acetate, potassium chloride and sodium carbonate were purchased from Carlo-Erba and ferric chloride from Merck.

Extraction

The stem and leaves were extracted separately. The crushed samples were extracted in 80% (v/v) methanol, standing in refrigerator overnight. Prior to the analysis, the mixture was cooled to room temperature and filtered.

Color analysis

The color measurement was performed by a colorimeter (CR 400 chromometer, Konika Minolta Sensing, Inc., Osaka, Japan) according to the Hunter color system, L* (Brightness: 100, white; 0, black), a* (+, red; -, green) and b* (+, yellow; -, blue). White ceramic (No: 19633162) was used for the calibration of the colorimeter.

Dry matter determination

Dry matter analysis was carried out by drying up to constant weight in the oven at 105 °C (AOAC, 2000).

Total ash determination

The total ash analysis was carried out by burning at 550 °C in the ash oven until white ash was obtained (AOAC, 2000).

Determination of pH

The samples were diluted with distilled water and kept overnight in refrigerator. Prior to the analysis, the samples were taken out from the refrigerator to reach room temperature. The pH was measured using a digital pH meter (Eutech Cyberscan, Singapore) with ±0.01 sensitive at 20 °C.

Crude protein analysis

Protein analysis was carried out according to the Kjeldahl method (AOAC, 2000).

Crude fat analysis

Crude fat was extracted with diethyl ether in a Soxhlet device for 8 hours (AOAC, 2000).

Crude fibre determination

The crude fibre was determined using Weende method (Carrier et al., 2010). Briefly, the crude fibre was determined after an acidic hydrolysis with a 1.25% (w/v) H_2SO_4 solution for 30 min under reflux, followed by an alkaline hydrolysis with a 1.25% (w/v) NaOH solution for 30 min under reflux. The residue is filtered and washed with alcohol. It is then calcinated at 550 °C after being dried at 105 °C.

Total phenolic content (TPC)

The total phenolic content was determined according to the Folin-Ciocalteau method (Singleton and Rossi, 1965). Briefly, the samples were extracted with 80% (v/v) methanol and filtered. A volume of 750 µl of 10% (v/v) Folin-Ciocalteu solution was added in 150 µl diluted sample and left to react for 5 minutes before adding 600 µl of 7.5% (w/v) sodium carbonate solution. The mixture was shaken again and placed in the dark for 2h before reading absorbance at 760 nm against blank by using a UV-VIS spectrophotometer (Helios Gamma). The standard curve drawn using gallic acid and the total phenolic content was expressed as mg GAE kg^{-1}.

FRAP assay

A volume of the diluted methanolic extract was mixed at 10:1:1 ratio with FRAP solution constituted of 300 mM acetate buffer (dissolved in 40 mM HCl): 20 mM $FeCl_3$: 10 mM TPTZ (2,4,6-tripyridyl-s-triazine). The assembly was shaken for about 5 minutes and the absorbance was read at 593 nm against a blank. FRAP values were expressed as µM of ferrous equivalent Fe (II) per g of dry sample (Tural and Koca, 2008).

DPPH assay

The DPPH (2,2-diphenyl-1-picrilhydrazyl) radical scavenging effect of the samples was determined following the previous method (Tural and Koca, 2008). 50 µL sample was mixed with 1 mL 100 µM

DPPH solution. The mixture was shaken and left to stand in dark for 3 h until the reaction completed. Thereafter, the absorbance was recorded at 517 nm against a control. The reduction ratio of DPPH was determined with the following equation:

$$\text{Reduction } (\%) = \left(\frac{A_C - A_S}{A_C}\right) \times 100 \qquad \text{(Eq.1)}$$

Where, A_c=Absorbance of control and A_s=Absorbance of extract. DPPH radical scavenging values were calculated using a calibration curve in mmol Trolox equivalents per g (mmol TE g^{-1}).

Extraction and determination of volatiles

The volatile compounds of Foxtail lily were analyzed for the stem and leaf parts using Headspace/Gas Chromatography/Mass Spectrometry (HS-SPME/GC-MS) according to the previous methods (Alasalvar et al., 2012; Shoko et al., 2014; Koca et al. , 2016) with slight changes.

Headspace-Solid phase microextraction/Gas Chromatography-Mass Spectrometry (HS-SPME/GC-MS)

1 g of samples was transferred into 22 mL headspace vials (Perkin Elmer, USA). The headspace vials were immediately sealed air-tight with a silicone/polytetra-fluoroethylene (PTFE) septum (Perkin Elmer, USA) and aluminum cover (Perkin Elmer, USA). The sample was then heated at 80 °C for 60 min and then put into headspace autosampler. The transfer line was a fused silica 1m x 320 µm. The vial pressure was set at 10 psi and column pressure at 25 psi. The needle temperature was set at 90 °C and transfer line temperatures at 100 °C. The trap hold time was 6 min, and the outlet split was on. Desorbed compounds were automatically injected into a GC column (Optima-Wax, 60 m length, 0.25 mm inner diameter, 0.25 µm film thickness). The oven temperature was 70 °C. The flow rate of the helium carrier gas was 1 mL min^{-1}. The injection was performed in the splitless mode (200 °C injection port temperature). The GC column temperature was programmed from initial holding at 35 °C for 5 min, from 35 °C to 160°C at a rate of 3 °C min^{-1} and then 15 min at 160 °C. The MS conditions were 200 °C for ion source temperature, 70 eV for ionization energy, 33-300 amu for mass scan range, 350 V electron multiplier voltage, 0.25 s for scan time, 0.05 for standby time, and electron ionization (EI) as ion mode. The analyses were performed in triplicate.

Identification of volatile compounds

The aroma compounds were determined by comparison of their retention index and their mass spectra with those of a commercial spectra database (Wiley 6, NBS 75k) and the instrument's internal library. 10 µL methyl alcohol:water (1:1) mixture was used as internal standard. The standard peaks were compared to those of samples based on their retention time and their mass spectra. The unknown chromatograms were identified by using Mass Spectral Libraries according to the retention index calculated thanks to n-alkane series (C_6-C_{20}).

Statistical analysis

The data were statistically evaluated by one way ANOVA and t test (ver. 21.0, SPSS) at a 0.05 level of significance.

Results and Discussion

Physico-chemical characteristics

The physico-chemical properties of stem and leaf parts of Foxtail lily (Çiriş) were assigned in Table 1.

Table 1. Physico-chemical and antioxidant characteristics of Foxtail lily

Characteristics	Stem	Leaf
L*	67.77±3.13 a	46.70±2.20 b
a*	-8.99±0.60 a	-12.85±1.02 b
b*	22.54±2.53 a	17.48±2.43 b
Moisture content, %	93.90±1.05 a	90.90±1.34 b
pH	5.01±0.14	5.01±0.11
Ash, %	0.48±0.06 b	0.70±0.12 a
Crude fibre, %	0.62±0.11 b	1.06±0.14 a
Crude protein, %	1.45±0.29 b	2.27±0.47 a
Crude fat, %	0.60±0.11	0.60±0.12
Total phenolic content, mg GAE kg^{-1}	897.75±105.90 b	1781.86±652.45 a
FRAP, µmol ISE g^{-1}	5.26±1.64 b	12.29±4.86 a
DPPH, mmol TE g^{-1}	40.81±12.20 b	89.55±10.71 a

*Means and standard deviations; Different letters in the same line show the significant differences between the values($p<0.05$).

The Foxtail lily stem and leaf had moisture content mean values of 93.90% and 90.90%. In some previous literatures, the moisture content range was reported as 86.62-92.00% (Tosun et al., 2012; Cinar et al., 2017). The highest moisture content was determined in the stem and the lowest in the leaf part. The pH was found to be 5.01 in both stem and leaf. This finding was found in agreement with the results Tosun et al. (2012) who have reported pH ranged from 4.78 to 5.14 in the aerial part of eight different Foxtail lily plants. The ash values were detected as 0.48% in the stem and 0.70% in the leaf part. The value detected in the leaf part was found to be accordance with the results of the previous studies (0.61-1.11%) (Tosun et al., 2012; Cinar et al., 2017), however, a lower total ash value was found in the stem. Likewise, the ash values detected in the stem and leaf parts in the present study were found lower than the values identified previously in Foxtail lily root powder (6.09%) (Pourfarzad and Najafi, 2015). The color characteristics of the stem were mixture color of lightness (L*=67.77), greenness (a*=-8.99) and yellowness (b*=22.54). Likewise, color properties of the leaf parts were mixture color of lightness (L*=46.70), greenness (a*=-12.85) and yellowness (b*=17.48). However, the leaf part of Foxtail lily was found less bright, greener and less yellow when compared to the stem. When comparing these color values to the literature, although the dried Foxtail lily high level fructan which had brightness character (L=37.41-71.20), it had higher a* value (a=0.68-4.06 (redness)) and lower b* value (b=7.13-11.13 (greenness)). When compared to the literature, due to its high fructan level, the brightness character L* of dried Foxtail lily varies between 37.41-71.20 it had a high a* value (a=0.68-4.06 (redness)) and low b* value (b=7.13-11.13 (greenness)) (Pourfarzad et al., 2015).

The average crude fibre was determined as 0.62% and 1.06% in Foxtail lily stem and leaf, respectively. These findings were found lower when compared to the previous study which has revealed 2.75% crude fibre in Foxtail lily leaf. These variations could be attributed to the cultural conditions, genetic and experimentation aspects. For the studied Foxtail lily in this work, the highest crude fibre was identified in the leaf part and lower in the stem (Table 1). The average crude fat was determined as 0.60% in both the stem and leaf parts. Similar crude fat of 0.46% has been reported previously in Foxtail lily leaf, however, higher crude fat of 7.23% has been detected in Foxtail lily root powder (Pourfarzad et al., 2015). The crude protein was 1.45% for the stem and 2.27% for the leaf. These results were found higher than the value reported by Cinar et al. (2017), however, the crude protein found in the stem was in accordance with that identified previously young Foxtail lily leaf (Tosun et al., 2012).

Antioxidant characteristics

The antioxidant properties encompassing total phenolic content, DPPH radical scavenging and FRAP values of Foxtail lily stem and leaf were given in Table 1. The average of total phenolic content was 897.75 GAE mg kg^{-1} in the stem and 1781.86

mg GAE kg^{-1} in the leaf. These findings were found lower than the values of total phenolic content reported in the previously in Foxtail lily (Karaman et al., 2011; Tosun et al., 2012; Falahi et al., 2019). However, Karadeniz et al. (2015) reported that the total phenolic content was lower than our results. Likewise, the total phenolic content of Foxtail lily leaf and root extracted with acetone has been found in accordance with our results, while the ethanolic and aqueous extracts have displayed lower values (Tuzcu et al., 2017). The total phenolic content detected in the stem was found lower when compared to value figured out in the leaf. The mean FRAP values were 5.26 and 12.29 mmol ISE g^{-1} in Foxtail lily stem and leaf, respectively. As can be seen, the highest FRAP values were detected in the leaf, while the lowest in the stem. The values of DPPH free radical scavenging were 40.81 and 89.55 mmol TE g^{-1} in the stem and leaf, respectively. These values were found higher than the values reported by Tosun et al. (2012), while lower than other previous studies (Falahi et al., 2019). The variations observed amongst the antioxidant properties of Foxtail lily could be associated with the genetic, cultivation conditions, analysis methods and the part analyzed. It was remarked that the total phenolic content, FRAP and DPPH values were higher in the leaf.

Volatile compounds

The headspace volatile compounds of Foxtail lily (stem and leaf parts) samples were presented as a percent with the linear retention index (LRI) values in Table 2.

Table 2. Headspace volatile compounds (%) of Foxtail lily.

No	LRI	RT	Volatile compounds	Stem	Leaf
			Aldehydes		
1	814	4.853	Acetaldehyde	22.95±8.66	13.64±12.57
2	1009	7.724	3-Methyl butanal	1.71±1.54	2.78±1.62
3	1158	13.571	Hexanal	0.15±0.14	0.12±0.09
			Total	24.81	16.54
			Alcohols		
4	1045	9.072	Ethyl alcohol	4.71±2.55	3.63±1.27
5	1333	20.551	2-Methyl-1-butanol	0.32±0.48	0.61±0.60
6	1819	40.444	3-Furfuryl alcohol	0.14±0.11	0.11±0.12
			Total	5.17	4.35
			Ester		
7	933	6.061	Methyl acetate	1.25±0.80	2.28±1.27
			Total	1.25	2.28
			Furan		
8	988	7.135	2-Methyl furan	0.12±0.07	0.34±0.37
			Total	0.12	0.34
			Sulfur compound		
9	868	5.204	Dimethyl sulfide	8.50±2.76	5.44±2.96
			Total	8.50	5.44
			Aliphatic hydrocarbon		
10	748	4.462	Hexane	2.10±0.76	2.53±0.69
			Total	2.10	2.53
			Volatile nitrogen		
11	1084	10.525	Methyl isocyanide	5.61±2.26	5.66±2.63
			Total	5.61	5.66
			General total	47.56	34.61

LRI: linear retention index calculated on DB-WAX capillary column Concentration: Means of three repetitions (%).

Eleven most abundant volatile compounds were detected in Foxtail lily stem and leaf, including three aldehydes, three alcohols, one ester, one furan, one sulfur compound, one nitrogen compound and one aliphatic hydrocarbon. In contrast, terpenes have been reported as the most dominant aromatic class in Foxtail lily, followed mainly by aldehydes, ketones, alcohols and esters (Karaman et al., 2011; Falahi et al., 2019). These differences might probably be associated with the cultivation conditions, extraction and analysis techniques since volatile

compounds have been reported to be very sensitive to the operating conditions (Roux et al., 2008; Koca et al. , 2016; Amanpour et al., 2019; Zannou et al., 2020). It has been mentioned before that 11 volatile compounds were detected representing about 47.56% and 34.61% of the total volatiles in the Foxtail lily stem and leaf, respectively. Despite differences determined in the amounts of volatile compounds of Foxtail lily stem and leaf, the pattern of these compounds was found to be quite similar ($p>0.05$) (Table 2). Acetaldehyde was the most abundant volatile compound discovered in the studied Foxtail lily samples, followed by dimethyl sulfide, methyl isocyanide and ethyl alcohol, respectively.

Aldehyde compounds.

Aldehydes were the most important volatile group of the studied Foxtail lily, representing 24.81% and 16.54% in stem and leaf, respectively. It is worth mentioning that aldehydes are widespread in plants and derived products as one of the major volatile groups which affect their overall aroma profile (Modise et al., 2004; Alasalvar et al., 2012; Amanpour et al., 2019). Three aldehyde compounds have been detected in Foxtail lily samples, including acetaldehyde as a major compound followed by 3-methyl-butanal and hexanal, respectively. The aldehydes identified for Foxtail lily and were mostly concentrated in the stem than leaf (Table 2). The volatile compounds might be short carbon chain aldehydes, alcohols, and esters produced in higher plants during the lipoxygenase (LOX) pathway. They gives characteristic flavor of vegetables, fruits and green leaves (Vincenti et al., 2019). The aldehydes have 6-9 carbons and are formed from fatty acids by lipoxygenase and hydroperoxide lyase enzymes (Choi et.al., 2017). The C6 and C9 aldehydes, alcohols and their esters give the typical odor of damaged leave and have a characteristic green and fruity smell. They are known as green-leaf volatiles which are responsible for fresh green aroma in vegetables and fruits (Vincenti et al., 2019). Fidler (1967) reported that the formation of acetaldehyde occurs naturally in plant tissues or through the metabolism of carbohydrate and acid, during fermentation under microbiological action on sugar and amino acids (Liu and Pilone, 2000), and through enzymatic reactions (Tajima et al., 1982). Some researchers explain the acetaldehyde is one of the key odorants in wine (Liu and Pilone, 2000) and cheese (Engels et al., 1997). Acetaldehyde and hexanal have been identified in strawberry (Modise et al., 2004), while 3-methylbutanal and hexanal have mentioned in black tea among major aroma compounds (Alasalvar et al., 2012). While acetaldehyde gives the green apple aroma, 3-methylbutanal and hexanal volatiles give the green, nutty and green grass aroma (Zhogoleva et al., 2023). The aldehydes can transform into the corresponding alcohols or esters (Engelberth and Engelberth, 2020).

Alcohol compounds.

Alcohols represented the second most significant aromatic compounds discovered in the present study. Alcohols are sub-products occurring during enzymatic (especially under lipoxygenase) and degradation of fatty acids (Chen et al., 1998). The highest amount of alcohol was dedected in the stem (5.17%), while the lowest in the leaf (4.35%) (Table 2). Three alcohols were identified in Foxtail lily, with ethyl alcohol as a major compound, followed by 2-methyl-1-butanol and 3-furfuryl alcohol, respectively. These compounds were reported for the first time in Foxtail lily. However, other aliphatic alcohols (2-ethyl-hexanol, 1-octanol, hexenol and 3,4-dimethylcyclohexanol) have been previously reported in Foxtail lily (Karaman et al., 2011; Falahi et al., 2019). Ethyl alcohol has been mentioned among the main aroma contributors of broccoli (Jacobsson et al., 2004) and black tea (Alasalvar et al., 2012), whereas furfuryl alcohol has been reported in roselle infusions (Zannou et al., 2020). Quantitatively, 3-methyl-l-butanol has been reported to be one of the major parts of the volatiles in apples (Aaby et al., 2002) and Cape Gooseberry (Yilmaztekin, 2013).

Sulfur and nitrogen compounds.

Dimethyl sulfide was the second most important volatile compound detected Foxtail lily samples. Volatile sulfur compounds have been widely reported in Cruciferous vegetables as responsible for objectionable sulfurous aromas and overcooked off-flavors (Chin and Lindsay, 1993). However, some sulfur-containing volatile compounds, such as hydrogen sulfide, which imparts a rotten egg-like aroma, impair the sensory quality of foods, while some sulfur compounds, such as 3-mercaptohexanol, which imparts fruitiness, have a positive effect on the taste and aroma of some fermented products such as wine (Swiegers and Pretorius, 2007). In this study, dimethyl sulfide was identified for Foxtail lily, and was determined as 8.50% in the stem and 5.44% in the leaf. Previously, dimethyl sulfide has been reported in cabbage (Chin and Lindsay, 1993), garlic (Koca et al., 2016), longleaf and ben fry (Falahi et al., 2019). Methyl isocyanide was the third most important volatile compound detected in Foxtail lily. It is a major volatile transformation product of the fumigant metam sodium which may have a risk on human health and environmental receptors (Geddes et al., 1995). In a study, dimethylsulfide and methyl isothiocyanate and methyl isocyanide volatiles identified in marine sponge extract were found to be responsible for antimicrobial activity and nauseating and toxic odor (Duque et al., 2001). In the present study, methyl isocyanide was determined as 5.66% and 5.61% in the foxtail lily leaf and stem, respectively. The studies have shown that methyl isocyanide is among the main volatile compounds of marine sponge (Duque et al., 2001; Pawlik et al., 2002) and körmen (Koca et al., 2016). It has been previously reported among major volatile compounds of the marine sponge (Duque et al., 2001; Pawlik et al., 2002) and körmen (Koca et al., 2016).

Other compounds.

Methyl acetate, 2-methyl furan and hexane were also detected among Foxtail lily headspace volatile constituents. In a previous study, methyl acetate in watermelon (Pino et al., 2003) and 2-methyl furan in malt (Dong et al., 2013) were found among the main volatile compounds.

Conclusion

In this study, some physical and chemical characteristics, antioxidant properties and determination of volatile compounds in stem and leaf parts of wild-grown Foxtail lily (*Eremurus spectabilis*) were evaluated. The results revealed significant differences in physical, chemical and antioxidant properties of stem and leaf. The highest total phenol content, FRAP and DPPH values were determined in the leaf part. 11 volatile compounds were detected in Foxtail lily stem and leaf, including 3 aldehydes, 3 alcohols, 1 ester, 1 furan, 1 sulfur compound, 1 nitrogen compound and 1 aliphatic hydrocarbon. Acetaldehyde, dimethyl sulfide, methyl isocyanide and ethyl alcohol were the most important volatile compounds detected in the headspace of Foxtail lily. The aromatic and bioactive compounds in its structure might vary depending on the geography where it grows. Foxtail lily, a wild herb and, in addition to being edible, it can be seen as a nutritious vegetable due to its bioactive components. The fact that the plant is not yet produced agriculturally causes it to be collected unconsciously from nature and limits its use only to local cuisines.

Conflict of Interest: The authors declare no conflict of interest.

Authors' Contribution: B.T. data collection, analysis, writing, editing, submitting the manuscript; İ.K. conceptualization, methodology, data collection, analysis and writing; O.Z. writing, review and editing; B.K. analysis.

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