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Investigation of Phenolic, Flavonoid and Total Antioxidant Capacity of Sumac (*Rhus Coriaria* L.) Plant Grown in Different Regions and Subjected to Different Preservation Methods

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Abstract

The total amount of phenolic and flavonoid compounds and the total antioxidant capacity of sumac samples grown in different regions were determined by a spectrophotometer. Freshly ground samples were divided into three parts: the first part was analyzed immediately, the second one was oiled, and the third one was kept as is for six months. The total phenolic and flavonoid compounds were found in between 27.73-51.75 µg GAE (g dw)$^{-1}$ and 16.16 -33.50 µg QE (g dw)$^{-1}$, respectively, for fresh samples. In the samples that were grounded and kept for six months, the same parameters were observed to be 19.31 - 37.75 µg GAE (g dw)$^{-1}$ and 10.76 - 21.82 µg QE (g dw)$^{-1}$, respectively. IC_{50} and TEAC values in freshly ground sumac samples were found between 14.79-23.80 µg mL^{-1} and 359.30-665.62 µmol trolox (g dw)$^{-1}$, respectively. IC_{50} and TEAC values in the samples oiled were determined to be in between 17.51 - 27.70 µg mL^{-1} and 306.69 - 517.40 µmol trolox (g dw)$^{-1}$, respectively. From these findings, it can be said that the higher the amount of total phenolic and flavonoid compounds in the samples, the better the total antioxidant capacity. The decreases in the examined parameters of the samples with oil are lower than those kept without oiling ($p>0.05$). The differences in the examined parameters can be explained by the differences in geographical and ecological conditions.

1. Introduction

Sumac (*Rhus coriaria*), which can grow all over the world, especially in subtropical and temperate climates, is a medicinal plant and is also used as a spice [1]. It is reported that in the traditional medicine of the Middle East and Iran, sumac has been used for centuries in the treatment of diseases such as dysentery, diarrhea, hemorrhoids, and gout, as well as for healing wounds and lowering blood sugar, cholesterol, and uric acid levels. It is also stated that sumac contains antibacterial, antifungal, antiviral, antioxidant, anti-inflammatory, hepatoprotective, xanthine oxidase inhibition, hypoglycemia, and cardiovascular protective activities [2]. Studies have reported that it contains many physiologic organic acids, including malic and citric acids, fatty acids, vitamins, flavonoids, and terpenoid derivatives [3], [4]. The proteins, organic acids, minerals, essential oils, vitamins, and phenolics contained in sumac are important for human health. Additionally, sumac is reported to be rich in phenolic chemicals, especially gallic acid and its derivatives, which have a strong antioxidant effect [1], [5]. The fruits and leaves of the sumac plant, which have great economic value, are used in the kitchen, medicine, leather, and dye industries [6]. Antioxidants are chemicals that shield living systems from damage caused by free radical

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oxidation [7]. Oxidative stress can occur when reactive oxygen species (ROS) are not effectively removed from the system. Secondary metabolites such as phytochemicals and especially phenolic compounds are known to have strong antioxidant effects [8].

Phenolic substances are important for human health due to their antimicrobial and antioxidant effects and enzyme inhibition [9]. Flavonoids are generally responsible for colour, the taste, prevention of fat oxidation, and the preservation of vitamins and enzymes in foods [10]. In addition to their properties such as antioxidant, antimutagenic, antiproliferative, antitumor, antiviral and anti-inflammatory, epidemiological studies have shown the importance of flavonoid compounds in reducing the risk of cardiovascular diseases and cancer [11].

Epidemiological studies show that foods have beneficial effects on human health, including their nutritional values. If ROS generated as a result of metabolic activities in living systems exceeds the antioxidant capacity of biological systems, oxidative stress occurs. Intake of antioxidants through food plays an important role in preventing various diseases, such as cancer and cardiovascular diseases, and delaying the aging process [12]. Therefore, it has become important to study the antioxidant capacity of many molecules naturally found in food and biological systems. Foods are sensitive to various environmental factors, such as moisture, light, oxygen, and microorganisms, and these factors can cause spoilage [13]. He et al. [14] report that ginger oil is turned into a film and used to preserve foods such as bread, meat, fish, and fruit. Some biochemical parameters in foods change depending on shelf life. Sumac samples are generally offered for consumption in ground form.

In this study, it was aimed at determining the total phenolic substances, flavonoids, and total antioxidant capacity of sumac grown in different regions. Freshly collected samples were grinded and divided into three parts, first part was analyzed immediately, and the second and third parts were kept for 6 months, with one part being oiled.

2. Material and Method

2.1. Materials

All sumac samples in Türkiye and Iraq were obtained freshly from public markets. After the samples were dried in an oven at 60 °C for 10 hours, they were ground in a blender and sieved (100 mesh) to separate their seeds and then divided into three parts.

The first group, which is freshly ground, was used immediately for the analysis, the second group was kept as is for 6 months in a plastic bag in the fridge at 4 °C. The third group was oiled by spraying sunflower oil and kept in a plastic bag in the fridge for 6 months at 4 °C. At the end of six months, the necessary analyses were performed similarly to the first group of samples.

2.2 Methods

Total phenolic, total flavonoid substances and total antioxidant capacity were determined according to Çakmak et al. [15].

2.3 Statistical analysis

All analyses were repeated three times, and the results are given as mean ± deviation. Findings were subjected to One-Way ANOVA using SPSS 26.0 for MS Windows. Differences between group means were analyzed for significance using the Tukey HSD test, and statistical significance was expressed as $p<0.05$. Significant differences in table rows are indicated by different numbers of * while the same numbers of * indicate there is no statistical difference between groups. The same letters in the table column indicate that there is no significant difference ($p>0.05$) between the regions.

3. Results and Discussion

Phenolic compounds, which are secondary metabolites in plants, are responsible for antioxidant effects. Flavonoids and other plant polyphenols are important antioxidants with high redox potentials. The antioxidant effects of phenolic compounds are explained by their binding of free radicals, chelating with metals, and inactivation of some enzymes [16]. Total phenolic and flavonoid substance amounts and total antioxidant capacity results, found as a result of different treatments applied to sumac grown in different regions, are given in Table 1-4.

Some biochemical parameters in foods change depending on shelf life. Sumac samples are generally sold for consumption in ground form. Therefore, ground and oiled sumac samples were analyzed after being kept for six months to simulate the average shelf life of the sumac on the market.

Table 1. Total phenolic substance in sumac samples (µg GAE (g dw)$^{-1}$).

Region	First group	Second group	Third group
Maraş	$^{b, c, d}$ 38.84 ± 1.11*	$^{c, d}$ 27.56 ± 1.01**	^{c} 30.72 ± 1.08***
Elazığ	^{e} 44.88 ± 1.49*	^{e} 35.80 ± 1.16**	^{d} 41.72 ± 1.28***
Shelaza	^{a} 29.42 ± 0.90*	^{c} 25.17 ± 0.78**	$^{a, b}$ 27.54 ± 0.92***
Trawanish	$^{b, c}$ 36.90 ± 1.09*	^{c} 26.45 ± 0.79**	^{c} 31.43 ± 0.90***
Shahi	^{a} 28.47 ± 0.98*	^{b} 21.27 ± 0.78**	^{a} 26.50 ± 0.80***
Charput	^{a} 28.40 ± 0.85*	^{b} 22.59 ± 0.79**	^{a} 25.17 ± 0.91***
Suleymania	^{f} 51.50 ± 1.46*	^{e} 36.55 ± 1.20**	^{d} 42.37 ± 1.27***
Kadana	^{a} 27.73 ± 0.92*	^{a} 19.31 ± 0.79**	^{a} 25.98 ± 0.85***
Derişke	$^{b, c}$ 36.00 ± 1.14*	^{c} 26.19± 0.93**	^{c} 30.78 ± 1.01***
Ranya	^{b} 35.67 ± 1.07*	^{d} 28.29 ± 0.91**	^{c} 32.32 ± 1.02***
Shalidize	^{f} 51.75 ± 1.48*	^{e} 37.75 ± 1.13**	^{d} 41.35 ± 1.28***

Table 2. Total flavonoids substance in sumac samples (µg QE (g dw)$^{-1}$).

Regions	First group	Second group	Third group
Maraş	^{d} 25.84 ± 1.16*	^{b} 14.62 ± 0.73**	^{b} 18.37 ± 0.86***
Elazığ	^{e} 30.37 ± 1.76*	^{d} 19.84 ± 1.13**	^{d} 27.75 ± 1.29***
Shelaza	^{a} 16.16 ± 0.79*	^{a} 10.76 ± 0.68**	^{a} 14.89 ± 0.65***
Trawanish	^{c} 20.21 ± 1.36*	^{c} 16.23 ± 0.84**	^{b} 18.55 ± 0.87***
Shahi	^{c} 20.11 ± 1.41*	^{a} 12.54 ± 0.94**	^{a} 14.34 ± 1.10***
Charput	^{b} 17.88 ± 0.89*	^{a} 12.83 ± 0.61**	^{a} 14.46 ± 0.80***
Suleymania	^{e} 33.50 ± 1.70*	^{d} 20.37 ± 1.08**	^{e} 30.88 ± 1.28***
Kadana	^{b} 18.40 ± 0.85*	^{a} 11.57 ± 0.66**	^{b} 16.76 ± 0.87***
Derişke	^{d} 25.82 ± 0.76*	^{d} 19.22 ± 0.84**	$^{c, d}$ 23.79 ± 1.36***
Ranya	^{c} 22.60 ± 1.16*	^{b} 14.27 ± 0.80**	^{b} 19.42 ± 1.12***
Shalidize	^{d} 28.52 ± 1.86*	$^{d, e}$ 21.82 ± 0.98**	^{c} 25.72 ± 1.13***

The total amount of phenolic substances in the first group grown in different regions varies between 27.73 ± 0.92 - 51.75 ± 1.48 µg GAE (g dw)$^{-1}$. It can be said that there is no significant difference between Sheladize and Süleymania, Shahi, Charput, Shelaza, and Kadana regions, as well as between Trawanish, Derişke, Ranya, and Maraş regions (Table 1). While the total amount of phenolic substances in the second, group of samples varies between 19.31 ± 0.79 - 37.75 ± 1.13, on the other hand, in the third group of samples, it varied between 25.17 ± 0.91- 42.37 ± 1.27 µg GAE (g dw)$^{-1}$. As seen in the rows of Table 1, the difference between the first, second and third groups is statistically significant ($p < 0.05$). The loss of phenolic substances in the third group is less than in the second group.

According to previous research, the methanol extract of sumac samples contained 151.71 mg GAE (g extract)$^{-1}$, and the ethyl acetate extract contained 65.31 mg GAE (g extract)$^{-1}$ total phenolic substance [17]. In a study conducted by Mazzara et al. [18], total phenolic and flavonoid substances in sumac samples taken from five different regions of Sicilian were between 354.81-473.08 mg GAE (g DE)$^{-1}$, 38.06 – 55.56 mg QE (g DE)$^{-1}$ respectively. Yuksel et al. [19] reported that the total amount of phenolic substances in the methanol extract of sumac samples grown in different regions of Tunceli varied between 797 ± 50 – 1929 ± 63 mg GAE (kg)$^{-1}$.

Flavonoids are generally responsible for color, taste, the prevention of fat oxidation, and the preservation of vitamins and enzymes in foods [20]. The total amounts of flavonoid substances in the sumac samples in the first, second and third groups ranged between 16.16-33.50, 10.76-21.82, 14.34-30.88 µg QE (g dw)$^{-1}$ respectively. Fereidoonfar et al. [21] reported that the amounts of total phenolic and flavonoid substances in the methanol extract of sumacs grown in various regions of Iran were determined to be in between 77.54-389.30 mg GAE (g dw)$^{-1}$ and 2.19-7.54 mg QE (g dw)$^{-1}$, respectively. Özaydin et al. [22] reported that the total phenolic and flavonoid substance in sumacs of the southeastern Anatolia region of Turkey was in the range of 26.3 -

82.2 mg GAE (g sumac)$^{-1}$, 7.4 - 7.55 mg catechin (g sumac)$^{-1}$, respectively.

At the end of the six-month waiting period, the loss in the total amount of phenolic and flavonoid substances in the third group was found to be less than in the second group. This can be explained by the oil film formed on the flakes of sumac samples, which prevents the oxidation of sumac in the air. Çakmak et al. [23] found that the total phenolic and flavonoid substance amounts in wild white hambeles fruits as 37.30 ± 2.10 µg GAE (g dw)$^{-1}$, 22.17 ± 1.15 µg QE (g dw)$^{-1}$, respectively. Adelakun et al. [24] report that essential oils have antimicrobial effects, so they can be applied to food products or incorporated into synthetic packaging films to extend the shelf life of foods. Konfo et al. [25] reported that essential oils, as well as natural antioxidants, are used in the preservation of foodstuffs. Falowo et al. [26] reported that 2% and 4% basil essential oil applied to ground beef increased oxidative stability and preserved color during storage. Karatas et al. [27] reported that vitamin loss was less in oiled samples than in unoiled red pepper flakes for a certain period.

Total antioxidant capacity in sumac samples was determined by the DPPH and TEAC methods. High IC_{50} values calculated in the DPPH method indicate low antioxidant capacity.

Total antioxidant capacity is a measure of the specific amount of free radicals scavenged by a sample. Antioxidant capacity measurements yield the amount of a heterogeneous mixture of antioxidants, which determines the total scavenging ability of the sample [28].

Table 3. Total antioxidant capacity (IC_{50}) in sumac samples according to the DPPH method (µg mL^{-1}).

Region	First group	Second group	Third group
Maraş	^{c} 18.81 ± 0.65 *	^{c} 28.03 ± 0.88 **	^{c} 22.69 ± 0.71 ***
Elazığ	^{b} 16.55 ± 0.61 *	^{b} 22.56 ± 0.69 **	^{b} 19.27 ± 0.64 ***
Shelaza	$^{c, d}$ 20.83 ± 0.61 *	^{b} 24.24 ± 0.71 **	^{c} 22.20 ± 0.69 ***
Trawanish	^{c} 19.12 ±0.61 *	^{b} 23.28 ± 0.67 **	^{c} 21.90 ± 0.66 ***
Shahi	^{e} 22.28 ± 0.57 *	^{d} 32.11 ± 0.90 **	^{d} 25.77 ± 0.80 ***
Charput	^{e} 23.04 ± 0.74 *	^{d} 30.37 ± 1.01 **	^{e} 27.70 ± 0.87 ***
Suleymania	$^{a, b}$ 15.75 ± 0.56 *	^{a} 19.42 ± 0.67 **	^{a} 17.51 ± 0.62 ***
Kadana	^{e} 23.80 ± 0.72 *	^{c} 27.69 ± 0.78 **	^{d} 25.78 ± 0.72 ***
Derişke	^{c} 19.86 ± 0.58 *	$^{b, c}$ 25.44 ± 0.77 **	^{c} 22.09 ± 0.67 ***
Ranya	$^{c, d}$ 20.66 ± 0.65 *	^{c} 28.33 ± 0.76 **	^{d} 24.90 ± 0.70 ***
Shalidize	^{a} 14.79 ± 0.48 *	^{a} 19.37 ± 0.68 **	^{a} 17.81 ± 0.57 ***

Table 4. Total antioxidant capacity in sumac samples according to the TEAC method (µmol trolox (g dw)$^{-1}$).

Region	First group	Second group	Third group
Maraş	$^{b, c}$ 544.27 ± 27.30 *	^{b} 332.90 ± 16.40 **	$^{b, c}$ 448.77 ± 20.05 ***
Elazığ	$^{c, d}$ 594.50 ± 26.30 *	^{b} 348.80 ± 17.11 **	^{c} 452.42 ± 18.17 ***
Shelaza	^{b} 515.81 ± 23.48 *	^{b} 326.37 ± 14.48 **	^{b} 433.73 ± 17.24 ***
Trawanish	^{b} 531.37 ± 26.60 *	$^{b, c}$ 364.30 ± 16.82 **	^{b} 437.37 ± 20.14 ***
Shahi	^{b} 502.37 ±25.71 *	^{b} 334.80 ±18.23 **	^{b} 413.83 ± 19.31 ***
Charput	^{b} 488.31 ± 23.13 *	^{b} 324.33 ± 16.93 **	^{b} 414.90 ± 18.93 ***
Suleymania	$^{c, d}$ 636.50 ± 25.00 *	^{c} 407.33 ± 18.03 **	^{d} 517.40 ± 20.17 ***
Kadana	^{a} 359.30 ± 15.82 *	^{a} 259.64 ± 11.83 **	^{a} 306.69 ± 13.13 ***
Derişke	^{b} 527.96 ± 24.61 *	^{c} 389.03 ± 17.06 **	$^{b, c}$ 450.30 ± 17.50 ***
Ranya	^{b} 525.43 ± 24.50 *	^{b} 345.83 ± 14.51 **	^{b} 437.45 ± 16.03 ***
Shalidize	^{d} 665.62 ± 28.12 *	^{c} 389.63 ± 17.82 **	^{d} 510.00 ± 20.45 ***

While the IC_{50} values in the first group samples varied between 14.79 - 23.80, it was determined that they were between 19.37 - 32.11, and 17.51 - 27.70 µg mL^{-1} in the second and third group samples, respectively. Among the findings, the highest antioxidant capacity was observed in

Shalidize region sumac samples, while the lowest was observed in Kadana. According to the IC_{50} values in the third group, the total antioxidant capacity was found to be higher than the second group.

Ereifej et al. [29] reported that the total phenolic substance in the methanol extract of sumac and turmeric samples at 20 °C were reported to be 271.4 and 187.1 mg GAE (100 g dw)$^{-1}$, respectively. In the same study, they found the IC_{50} values of sumac and turmeric methanol extracts to be 0.15 and 0.16 mg mL^{-1}, respectively, according to the DPPH method.

While TEAC values in fresh sumac samples from different regions were found to be in between 359.30 - 665.62 µmole trolox (g dw)$^{-1}$ in the second and third groups, they vary between 259.64 - 407.33 and 306.69 - 517.40 µmole trolox (g dw)$^{-1}$, respectively. The difference between the groups is statistically significant ($p<0.05$), and at the end of the waiting period, the decrease in TEAC values in the second group is greater than in the third group. Isgrò et al. [30] stated that the IC_{50} value of the sumac sample was 0.41 ± 0.02 mg mL^{-1} and the TEAC value was 1.76 ± 0.10 mmol troloxs E (g extract)$^{-1}$. Cakmak et al. [23] reported that the IC_{50} and TEAC values in wild white hambeles fruits were 39.21 ± 1.25 µg mL^{-1} and 295.08 ± 12.50 µmol troloxs (g dw)$^{-1}$, respectively. Ayas et al. [31] reported that the TEAC values of Rhus coriaria, Nasturtium officinale and Scolymus hispanicus were 3055.6 ± 20.4, 903.0 ± 17.7, 539.0 ± 6.4 µmole trolox equivalent (g sample)$^{-1}$, respectively. Fereidoonfar et al. [21] reported that the total antioxidant capacity in the methanol extract of Iranian sumac was between 1.55-11.09 AAE (g dw)$^{-1}$.

It was observed that the total phenolic and flavonoid substance and total antioxidant capacity of all sumac samples decreased significantly compared to freshly ground ones. However, the amount of decrease is lower in the oiled samples. The reason why the loss in the parameters examined in oiled samples is less can be explained by the fact that the oil forms a film layer on the sumac surface.

4. Conclusion and Suggestions

It was found that the Shalidize, Süleymania, and Elazığ regions were richer than other regions in terms of total phenolic and flavonoid substances. It was concluded that the richest regions in terms of antioxidant capacity were Süleymania and Shalidize, while the poorest regions were Carput and Kadana. In regions where the total amount of phenolic and flavonoid substances is high, antioxidant capacity was also found to be high. The loss of measured values in an oiled sample is less than in the samples kept without oil. Sumac is thought to be a potential source for functional food production due to its high amount of phenolic compounds and antioxidant capacity. Differences in total phenolic, flavonoid, and antioxidant capacity amounts between regions might depend on geographical and ecological conditions.

Based on these results, it can be said that preserving sumac samples by oiling them for long-term consumption is more advantageous in terms of reducing the loss of phenolic substances, flavonoid, and antioxidant capacity.

Author Contributions

All the authors have contributed equally.

Conflict of Interest Statement

There is no conflict of interest between the authors.

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