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Araştırma Makalesi / Research Article

Investigation of Water-Soluble Vitamins in Sumac (*Rhus Coriaria* L.) Grown in Different Regions and Subjected to Different Preservation Methods

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Abstract

The amounts of water-soluble vitamins in unoiled and oiled sumac samples grown in different regions were determined by HPLC. For this purpose, the ground samples were divided into two parts, one part was oiled, while the other part was kept as is for six months and then analyzed. It was found that the amounts of ascorbic acid, thiamine, riboflavin, nicotine amide, nicotinic acid, pantothenic acid, pyridoxine, folic acid and cyanocobalamin in sumac samples kept for six months unoiled varied between 22.2 ± 1.1 - 48.8 ± 1.9, 38.9 ± 1.7 - 123.1±4.1, 123.8 ± 7.3 - 404.7 ±14.6, 5.8±4.5 - 203.8±8.5, 527.9±10.9 - 993.8±20.4, 216.7±7.7 - 575.4±13.7, 72.2±3.8 - 244.2±9.2, 359.2±14.1 - 612.8± 19.5, 43.0±2.2 - 108.8±4.8 µg /g dw, respectively. The difference between the amounts of water-soluble vitamins in oiled and unoiled sumac samples for all regions is statistically significant (P<0.05). It was also found that the vitamin loss in oiled samples were less than unoiled samples.

Keywords: *Rhus coriaria* L., Water soluble vitamins, Preservation.

Farklı Bölgelerde Yetişen ve Farklı Muhafaza Yöntemlerine Tabi Tutulan Sumak (*Rhus Coriaria* L.)' daki Suda Çözünen Vitaminlerin Araştırılması

Özet

Farklı bölgelerde yetişmiş, sumak örneklerinden yağlanıp ve yağlanmadan bekletilen numunelerdeki, suda çözünen vitaminler HPLC ile tayin edildi. Bu amaçla, öğütülen sumak örnekleri iki kısma ayrıldı, bir kısmı yağlanırken diğer ikinci kısım ise yağlanmadı ve her iki grup altı ay bekletildikten sonra analiz edildi. Yağlanmamış sumak örneklerindeki askorbik asit, tiamin, riboflavin, nikotin amid, nikotinik asit, pantotenik asit, pridoksin, folik asit ve siyanokobalamin miktarları sırasıyla 22.2 ± 1.1 - 48.8 ± 1.9, 38.9 ± 1.7 - 123.1±4.1, 123.8 ±7.3 - 404.7 ±14.6, 5.8±4.5 - 203.8±8.5, 527.9±10.9 - 993.8±20.4, 216.7±7.7 - 575.4±13.7, 72.2±3.8 - 244.2±9.2, 359.2±14.1 - 612.8± 19.5, 43.0±2.2 - 108.8±4.8 µg /g dw, arasında değiştiği bulunmuştur. Bütün bölgelerdeki yağlanmış ve yağlanmamış sumak örneklerindeki vitamin miktarları arasındaki farkın istatiksel olarak anlamlı (P<0.05) olduğu bulunmuştur. Ayrıca yağlanmış örneklerdeki vitamin kayıplarının yağlanmamış örneklere göre daha az olduğu belirlenmiştir.

Anahtar Kelimeler: *Rhus coriaria* L., Suda çözünen vitaminler, Koruma.

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1. Introduction

Sumac (*Rhus coriaria*), which can grow all over the world, especially in subtropical and temperate climates which is a medicinal plant and also used as a spice (Batiha et al., 2022). 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 (Morshedloo et al., 2018). Studies have reported that it contains many physiologically active components such as tannins, anthocyanins, organic acids including malic and citric acid, fatty acids, vitamins, flavonoids and terpenoid derivatives (Shabbir, 2012; Khalil et al., 2021).

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 (Rad and Khaleghi, 2020; Batiha et al., 2022). The fruits and leaves of the sumac plant, which has great economic value, are used in the kitchen, medicine, leather and dye industries (Abu-Reidah et al., 2015). Vitamins are chemical compounds that are necessary for life but can only be consumed in small doses. Vitamins are classified not by their external appearance but by the biological and chemical roles they play in the body. Vitamins have several roles in biochemical processes. Some, such as vitamin A, regulate cellular development and differentiation, while others, such as vitamin D, regulate mineral metabolism. Some, like vitamins E and C, have antioxidant properties (Asensi-Fabado and Munné-Bosch, 2010). Ascorbic acid (vitamin C) and dehydroascorbic acid are the two L-isomers that make up vitamin C, which is a redox system. Vitamin C is the active, stable form of vitamin C in tissues. Vitamin C, when used as a cofactor or antioxidant, is oxidized to the more unstable dehydroascorbic acid, which is readily "recycled" back to vitamin C through various enzyme networks, such as glutathione-dependent systems or reduced nicotinamide adenine dinucleotide phosphate dependent systems (Schlueter and Johnston, 2011). Cofactors or precursors, such as the B-complex vitamins, aid enzymes in their catalytic function throughout metabolism. In this context, vitamins may be thought as one of the prosthetic groups, with biotin, for instance, being a component of the enzymes responsible for fatty acid formation. They may also be loosely coupled to enzyme catalysts in their roles as coenzymes, which facilitate the transfer of chemical groups or electrons between molecules. For instance, methyl, formyl, and methylene groups are all possible for folic acid to transport in a cell. Perhaps the most well-known function of vitamins is their participation in the substrate reactions of enzymes (Smith et al., 2007).

Sumac samples are generally offered for consumption in ground form and used all around the year. Foods are sensitive to various environmental factors such as moisture, light, oxygen and microorganisms, and these factors can cause spoilage (Redfearn et al., 2023). It has been reported by Parvathi et al. (2021) that storage condition is important for some biochemical parameters of the pepper. To stop the degradation of food, different methods applied such as drying, freezing or protecting from oxygen and light. He et al. (2023) used ginger oil film to preserve foods such as bread, meat, fish and fruit. The aim of this work is to investigate the effect of using oil as protecting film over the sumac samples to increase the shelf life and reduce the vitamin loss.

2. Material and Methods

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 (Fakir Hausgrate 220 Watt),) and sieved through 100 mesh sieve to separate their seeds and then divided into two parts one of which is oiled (5.0 % w/w) with sunflower oil and other kept without oiling. All samples were stored in a plastic bag in the refrigerator at 4 °C for 6 months.

2.2. Methods

Analysis of water soluble vitamins

1.0 mL of 0.5 M $HClO_4$ was added to 1.0 g of ground sumac sample and vortexed for 1.0 min. The total volume was brought to 5.0 mL with distilled water and sonicated for 10 minutes (Wise Clean, WUC-AO3H, 170 W). It was then centrifuged at 4500 rpm for 10 minutes and the supernatant was transferred to 1.0 mL HPLC vials. SHIMADZU, 3D Model HPLC equipped with Prominence-I LC-2030C PDA detector was used for the analysis of water-soluble vitamins using a gradient program on an Inter Sustain AQ-C18 (5 µm, 150 x 4.6 mm I.D.) column, according to the method and conditions applied by Ali et al. (2024).

2.3. Statistical analysis

All analyses were repeated three times and the results are given mean ± standard 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 ($p>0.05$) in the regions.

3. Results and Discussion

It is well known fact that composition of foods change depending on time and storage conditions. Therefore, we see a best before date on the most foods on the market. To increase the shelf life of the foods, the most common practice is to make a barrier between food and environment, such as placing a plastic wrap, tin container. Sumac samples are generally sold for consumption in ground form mainly open to air in open market. One of the preservation methods is to form thin film around the food by edible oil such as linseed oil, corn oil. To find the effect of using vegetable oil on the shelf life of the sumac, ground unoiled and oiled sumac samples were analyzed after being kept for six months. In our previous work, Ali et al. (2024) water soluble vitamin contents of fresh sumac samples from different regions were performed given Table 1. The amounts of water-soluble vitamins of sumacs from different regions, kept for six months without oiling or oiled, are given in Tables 2-6. Vitamin loss of the oiled and unoiled sumac samples in comparison with fresh sumac samples in given in Table 2-6.

Table 1a. Amounts of water-soluble vitamins in fresh sumac samples from different regions (µg /g dw) (Ali et al. 2024).

Regions	Ascorbic acid	Thiamine	Riboflavin	Nicotinamide	Nicotinic acid	Pantotenic acid	Pyridoxine	Folic acid	Cyanocobalamine
Maraş	67.2 ± 4.1	105.8 ± 6.0	397.3 ±11.3	151.8 ± 4.7	879.6 ± 32.4	609.7 ± 21.8	385.8 ± 14.2	535.8 ± 18.2	104.1 ± 8.5
Elazığ	42.9 ± 4.5	107.4 ± 5.9	439.2 ± 20.9	268.6 ± 12.1	1005.7 ± 29.3	779.2 ± 22.8	183.2 ± 7.2	600.2 ± 37.3	155.2 ± 9.1
Shelaza	36.6 ± 2.0	87.9 ± 3.7	358.5 ± 13.7	314.0± 14.3	1140.8 ± 36.7	449.3± 24.3	168.2± 8.6	826.2± 62.0	177.4± 10.9
Trawanish	50.6 ± 3.0	71.9 ± 2.5	270.1 ± 9.0	157.9 ± 10.2	788.7 ± 15.5	775.1 ± 32.4	158.4 ± 9.0	584.2 ± 33.9	105.7 ± 4.4
Shahi	66.6 ± 2.2	78.3 ± 4.5	182.3 ± 10.9	130.9 ± 8.8	801.7 ± 15.4	336.2 ± 15.3	356.0 ± 11.9	663.4 ± 14.0	147.7 ± 9.1
Charput	64.1 ± 3.3	61.1 ± 2.5	255.1 ± 12.1	105.6 ± 6.9	913.2 ± 14.2	590.5 ± 29.4	123.8 ± 6.5	730.8 ± 21.3	154.1 ± 7.5
Suleymania	78.9 ± 3.2	135.9 ± 8.7	449.0 ± 21.4	117.7 ± 10.3	1084.0 ± 24.4	512.9 ± 26.5	242.2 ± 12.2	506.6 ± 15.7	94.6 ± 6.4
Kadana	68.0 ± 5.1	71.3 ± 5.7	199.7 ± 9.9	190.8 ± 11.6	834.1 ± 22.6	549.7 ± 27.4	157.3 ± 6.0	689.4 ± 32.5	164.0 ± 8.9
Derişke	43.4 ± 2.5	75.0 ± 4.6	362.2 ± 10.4	170.6 ± 1.9	1153.6 ± 21.7	301.7 ± 5.2	133.4 ± 7.1	516.0 ± 14.3	159.2 ± 13.3
Ranya	45.3 ± 2.2	144.5 ± 6.8	359.6 ± 12.6	135.7 ± 6.5	1054.4 ± 26.8	777.5 ± 43.0	244.2 ± 14.0	563.6 ± 26.9	73.9 ± 4.1
Shalidize	70.3± 3.5	173.6 ± 9.6	518.4± 28.6	257.1 ± 11.3	1292.1 ± 35.8	356.6 ± 12.3	208.8 ± 11.3	473.1 ± 28.6	192.6 ± 9.1

Table 2. Amounts of ascorbic acid and thiamine in pretreated sumac samples from different regions (µg /g dw)

Regions	Ascorbic acid Unoiled	% loss	Ascorbic acid Oiled	% loss	Thiamine Unoiled	% loss	Thiamine Oiled	% loss
Maraş	^{c}34.6 ± 2.0*	48.5	^{c}43.3±2.2**	35.6	^{f}79.2 ± 2.9*	25.1	^{d} 91.8±3.9**	13.2
Elazığ	^{a}23.4± 1.1*	45.5	^{b}37.0±1.8**	13.8	^{e}71.9 ± 2.6*	33.1	^{d} 94.0±3.7**	12.5
Shelaza	^{a}22.2 ± 1.1*	39.3	^{a}31.0±1.7**	15.3	^{d}64.4 ± 2.4*	26.7	^{c}75.4±3.4**	14.2
Trawanish	^{c}36.5 ± 1.3*	27.9	^{c}45.6±2.1**	9.9	^{b}48.5 ± 1.8*	32.5	^{b}60.6±3.2**	15.7
Shahi	^{e}45.6 ± 2.2*	31.5	^{e}56.8±2.4**	14.7	^{c}54.1 ± 1.9*	30.9	^{b}66.1±3.0**	15.6
Charput	^{c}36.0 ± 1.4*	43.8	^{d}50.2±2.3**	21.7	^{a}38.9 ± 1.7*	36.3	^{a}50.0±2.5**	18.2
Suleymania	^{e}48.5 ± 1.9*	38.5	^{f}67.1±3.0**	15.0	^{g}90.5 ± 3.4*	33.4	^{e}115.0±4.8**	15.4
Kadana	^{d}39.4 ± 1.4*	42.1	^{e}56.0±2.8**	17.6	^{b}45.4 ± 2.0*	36.3	^{b}62.8±3.4**	11.9
Derişke	^{b}30.1 ± 1.1*	30.6	^{b}36.2±1.6**	16.6	^{b}48.2 ± 2.1*	35.7	^{b}64.6±3.3**	13.9
Ranya	^{c}35.0 ± 1.6*	22.7	^{c}41.7±2.2**	7.9	^{g}95.7 ± 3.7*	33.8	^{f}127.2±4.8**	12.0
Shalidize	^{e}48.8 ± 1.9*	30.6	^{e}61.3±2.8**	12.8	^{h}123.1±4.1*	29.1	^{g}150.7±5.1**	13.2

$^{a-g}$ Values with different superscripts within the same column and number of ***** in the same row differ significantly at $P<0.05$

Table 3. Amounts of Riboflavin and nicotinamide in pre-treated sumac samples from different regions (µg /g dw)

Regions	Riboflavin Unoiled	% loss	Riboflavin Oiled	% loss	Nicotinamide Unoiled	% loss	Nicotinamide Oiled	% loss
Maraş	^{e}302.2 ±9.8*	23.9	^{e}355.6 ±11.0**	10.5	^{b}98.0±5.3*	35.4	^{c}123.0±6.4**	19.0
Elazığ	^{e} 311.3 ±9.9*	29.1	^{f}387.3 ±11.6**	11.8	^{e}195.2±7.8*	27.3	^{e}221.7±9.4**	17.5
Shelaza	^{d}297.8 ±9.3*	16.9	^{d}321.4 ±10.8**	10.3	^{e}203.8±8.5*	35.1	^{f}243.3±9.1**	22.5
Trawanish	^{b}196.1 ±7.4*	27.4	^{c}243.1 ±8.4**	10.0	^{b}97.6±5.8*	38.2	^{c}119.0±5.2**	24.6
Shahi	^{a}123.8 ±7.3*	32.1	^{a}157.5 ±7.9**	13.6	^{a}74.4±4.6*	43.2	$^{a.b}$98.2±4.8**	25.0
Charput	^{b}182.7 ±8.1*	28.4	^{b}205.2 ±8.4**	19.6	^{a}65.8±4.5*	37.7	^{a}85.0±4.4**	19.5
Suleymania	^{f}337.7 ±12.0*	24.8	^{f}407.1 ±14.1**	9.3	^{a}68.5±4.7*	41.8	^{a}92.4±4.6**	21.5
Kadana	^{a}119.6 ±6.1*	40.1	^{a}168.2 ±7.5**	15.8	$^{b.c}$114.7±6.1*	39.9	^{d}149.7±7.5**	21.5
Derişke	^{c}257.7 ±9.5*	28.9	^{d}319.3 ±11.9**	11.8	^{b}108.8±5.7*	36.2	^{d}145.2±7.6**	14.9
Ranya	^{d}281.5 ±9.8*	21.7	^{d}308.5 ±10.9**	14.2	^{a}77.8±4.4*	42.7	^{b}105.8±5.4**	22.0
Shalidize	^{g}404.7 ±14.6*	21.9	^{g}478.1 ±15.9**	27.1	^{d}170.2±7.2*	33.8	^{e}211.0±9.5**	17.9

$^{a-g}$ Values with different superscripts within the same column and number of ***** in the same row differ significantly at $P<0.05$

Table 4. Amounts of nicotinic acid and pantothenic acid in pre-treated sumac samples from different regions (µg /g dw)

Regions	Nicotinic acid Unoiled	% loss	Nicotinic acid Oiled	% loss	Pantotenic acid Unoiled	% loss	Pantotenic acid Oiled	% loss
Maraş	^{d}703.3±18.8*	20.0	^{c}778.1±16.3**	11.5	^{e}448.4±12.3*	26.5	^{f}546.3±16.1**	10.4
Elazığ	^{e}810.8±19.8*	19.4	^{f}931.0±22.0**	7.4	^{g}575.4±13.7*	26.2	$^{g.h}$690.6±18.6**	11.4
Shelaza	^{f}940.2±20.6*	17.6	^{g}1043.7±27.8**	8.6	^{c}302.9±8.5*	32.6	^{c}393.9±13.7**	12.3
Trawanish	^{a}527.9±10.9*	33.1	^{a}612.0±15.1**	22.4	^{g}570.±13.0*	26.5	^{g}677.6±16.5**	12.6
Shahi	^{b}590.1±14.5*	26.4	^{b}710.4±17.6**	11.4	^{b}241.7±7.8*	28.1	^{b}296.0±8.5**	12.0
Charput	^{c}652.1±15.9*	28.6	^{d}816.0±18.1**	10.6	^{d}404.1±14.0*	31.6	$^{d.e}$493.0±13.2**	16.5
Suleymania	^{e}854.9±21.9*	21.1	^{f}950.5±21.4**	12.3	^{d}388.1±11.9*	24.3	^{d}445.6±15.0**	13.1
Kadana	^{b}601.3±12.9*	27.9	^{b}700.4±16.5**	16.0	^{d}407.9±12.0*	25.8	^{d}475.7±16.5**	13.5
Derişke	^{e}815.0±16.5*	29.4	^{f}973.6±21.4**	15.6	^{a}216.7±7.7*	28.2	^{a}261.5±6.1**	13.3
Ranya	^{d}710.8±15.4*	32.6	^{e}862.4±19.6**	18.2	^{f}495.4±11.4*	36.3	^{g}654.6±17.1**	15.8
Shalidize	^{h}993.8±20.4*	23.1	^{g}1003.1±21.5**	22.4	^{a}223.9±6.9*	37.2	^{a}272.9±7.9**	23.5

$^{a-h}$ Values with different superscripts within the same column and number of ***** in the same row differ significantly at $P<0.05$

Table 5. Amounts of pyridoxine and folic acid in pre-treated sumac samples from different regions (µg /g dw)

Regions	Pyridoxine Unoiled	% loss	Pyridoxine Oiled	% loss	Folic acid Unoiled	% loss	Folic acid Oiled	% loss
Maraş	^{g}244.2±9.2*	36,7	^{f}300.0±10.8**	22,2	^{a,b}399.0±13.1 *	25,5	^{b}475.7±15.9**	11,2
Elazığ	^{c}117.9±5.9*	35.6	^{c}142.8±5.3**	22.1	^{d} 468.5± 14.4*	21.9	^{b}516.8±17.5**	13.9
Shelaza	^{b}90.5±4.7*	46.2	^{b}123.1±4.8**	26.8	^{g}612.8± 19.5*	25.8	^{e}726.1±21.5**	12.1
Trawanish	^{b}89.5±4.6*	43.5	^{b}117.4±4.8**	25.9	$^{a.b}$391.5±13.4 *	33.0	^{b}495.5±16.8**	15.2
Shahi	^{g}235.7±8.0*	33.8	^{f}285.4±9.7**	19.8	^{d}474.0± 15.7*	28.5	^{c}582.5±18.1**	12.2
Charput	^{a}77.7±4.0*	37.2	^{a}95.7±4.3**	22.7	^{f}570.8±20.6 *	21.9	^{d}633.4±20.6**	13.3
Suleymania	^{e}154.8±5.9*	36.1	^{e}199.6±7.9**	17.6	^{a}366.5± 12.8*	27.7	$^{a.b}$449.9±15.1**	11.2
Kadana	^{b}89.7±4.1*	43.0	^{b}120.0±5.5**	23.7	$^{d.e}$507.7±17.9 *	26.4	^{c}590.8±18.7**	14.3
Derişke	^{a}72.2±3.8*	45.9	^{a}95.2±4.5**	28.6	^{a}386.8±14.3 *	25.0	^{a}443.6±15.3**	14.0
Ranya	^{f}166.1±5.7*	32.0	^{e}192.4±7.8**	21.2	$^{b.c}$407.7±15.5 *	27.7	^{b}499.1±17.3**	11.4
Shalidize	^{d}134.8±4.9*	35.4	^{d}177.4±7.4**	15.0	^{a}359.2±14.1 *	24.1	^{a}414.3±15.0**	12.4

$^{a-g}$ Values with different superscripts within the same column and number of * in the same row differ significantly at P<0.05

Table 6. Amounts of cyanocobalamin in pre-treated sumac samples from different regions (µg /g dw)

Regions	Cyanoco-balamin Unoiled	% loss	Cyanoco-balamin Oiled	% loss
Maraş	^{b}50.3±4.0*	51.7	^{b}73.6±4.1**	29.3
Elazığ	^{d}75.4±4.6*	51.4	^{d}108.4±5.0**	30.2
Shelaza	^{f}104.0±5.0*	41.4	^{f}134.2±6.0**	24.4
Trawanish	^{c}62.4±4.3*	41.0	^{c}85.6±4.5**	19.0
Shahi	^{d}75.8±3.8*	48.7	^{d}104.0±5.9**	29.6
Charput	^{d}83.5±5.2*	45.8	^{d}112.9±6.1**	26.7
Suleymania	^{b}53.5±2.3*	43.4	^{b}72.2±4.0**	23.7
Kadana	$^{d.e}$87.8±4.7*	46.5	^{f}128.4±5.9**	21.7
Derişke	^{e}90.8±4.7*	43.0	$^{d.e}$115.6±5.7**	27.4
Ranya	^{a}43.0±2.2*	41.8	^{a}58.9±3.4**	20.3
Shalidize	^{f}108.8±4.8*	43.5	^{f}133.0±6.3**	30.9

$^{a-f}$ Values with different superscripts within the same column and number of * in the same row differ significantly at P<0.05

The vitamin content of foods depends on many factors such as genetic, ecological, drying method, preservation procedures and storage time. It is reported that vitamins are sensitive organic molecules that are easily affected by light, heat, moisture and oxygen (Santhi, et al., 2020). Ascorbic acid, which cannot be synthesized in the body, plays a role in collagen formation, epinephrine and carnitine synthesis, leukocyte function, iron absorption, folic acid metabolism and other enzyme processes (Masaki, 2010).

The amount of ascorbic acid in sumacs from different regions, kept unoiled and oiled, varies between 22.2 ± 1.1 - 48.8 ± 1.9, 31.0 ± 1.7 - 67.1 ± 3.0 µg /g dw, respectively. Ali et al. (2024) reported that the amount of ascorbic acid in fresh sumac grown in different regions varied between 36.6 ± 2.0 - 78.9 ± 3.2 µg /g dw. Compared to fresh sumac samples, it was determined that the loss of ascorbic acid in percent in unoiled sumac samples varied between 22.7-48.5, while in oiled samples it varied between 7.9-35.5 (Table 2).

Manas (2014) reported that the amount of ascorbic acid in turmeric, chilli, ginger, cumin and clove spices was 0.75, 5.55, 0.48, 0.09, 0.14 mg/g, respectively. Previous research by Kossah et al. (2009), determined that the quantities of ascorbic acid present in Syrian and Chinese sumac were, respectively, 38.91 ± 0.27 and 13.90 ± 0.20 mg/kg. Çöteli and Karataş (2104) reported in their study that 37% of vitamin C taken from parsley into aqueous solution was oxidized after approximately 8 hours.

Thiamine pyrophosphate is an important coenzyme and plays a key role in carbohydrate metabolism and other energy production pathways (Engin et al., 2016). The amount of thiamine in the oil-free and oily samples of sumacs from different regions varies between 38.9 ± 1.7 - 123.1±4.1, 50.0±2.5 - 150.7±5.1µg /g dw, respectively. When compared to the thiamine amounts in fresh sumacs samples given in Table 1a, the percentage loss of thiamine in unoiled and oiled samples in all regions were found to be in between 25.1-36.3 and 11.9-18.2, respectively.

Riboflavin, which acts as a co-enzyme in redox reactions in the body, is necessary for the release of energy from foods and the conversion of tryptophan into niacin (Schellack, 2015).

It was determined that the amount of riboflavin in oiled sumac samples ranged between 157.5 ±7.9 - 478.1±15.9, while in unoiled samples it varied between 123.8 ±7.3 - 404.7 ±14.6 µg /g dw. Compared to fresh samples, the percentage loss of riboflavin in oiled and unoiled samples for the regions varies between 9.3-27.1, 16.9-40.1, respectively (Table 3). As per the results of an earlier research by Ayoade et al. (2023), the amounts of riboflavin (B2) detected in cloves, black pepper, and turmeric were 29.15 ± 0.06 mg/100 g, 28.91 ± 0.03 mg/100 g and 40.36 0.03, respectively.

Vitamin B3 consists of nicotinic acid, nicotinamide and various enzymatic forms. This vitamin plays a crucial role in human health by facilitating energy synthesis and supporting antioxidant defense mechanisms (Maqbool et al., 2017). The amounts of nicotine amide and nicotinic acid in unoiled samples varied between 65.8±4.5 - 203.8±8.5, 527.9±10.9 - 993.8±20.4, respectively, while in oiled samples 85.0±4.4 - 243.3±9.1, 612.0±15.1 - 1043.7±27.8 µg /g dw. The percentage losses of nicotine amide and nicotinic acid in unoiled sumac samples varies in between 27.3 - 43.2 and 17.6 - 33.1, respectively. Based on a prior study conducted by Kossah et al. (2009), the Syrian and Chinese sumac were found to have 17.95 ± 0.28 and 2.39 ± 0.13 mg/kg of nicotinamide, respectively [31].

In their study, Seal and Chaudhuri (2017) provided data on the vitamin B3 content in several plant species, namely M. indica, M. laxiflora, S. gilo, S. kurzii, and V. foetidum. They reported the values of vitamin B3 in these species were 4.43 ± 0.03, 15.04 ± 0.08, 0.43 ± 0.008, 0.28 ± 0.008, and 0.13 ± 0.003 mg/100 gm dry plant material, respectively.

Pantothenic acid (Vitamin B5) serves as a precursor to coenzyme A, a necessary cofactor in the TCA cycle for fatty acid oxidation (Kennedy, 2016). The amount of pantothenic acid in unoiled sumac samples was determined to be between 216.7±7.7 - 575.4±13.7, while it was determined to be

272.9±7.9 - 690.6±18.6 µg /g dw in oiled samples. Pantothenic acid loss in unoiled and oiled sumacs of different regions varies between 24.3-37.2, 10.4-23.5, respectively (Table 4).

Shin and Choung (2023) reported that the amount of pantothenic acid in red pepper is 0.244 ± 0.006 mg/100 g. The amount of pantothenic acid in turmeric (*Curcuma longa* L.) has been reported to be 1.040 ± 0.028 mg/100g (Oh and Kim, 2019). Study conducted by Oh and Kim (2019), on the pantothenic acid in turmeric (*Curcuma longa* L.) and reported the pantothenic acid content as 1.040 ± 0.028 mg/100g.

Pyridoxine, pyridoxal, and pyridoxamine are all different forms of vitamin B6. Both pyridoxal phosphate and pyridoxamine phosphate, which are produced from vitamin B6, play critical roles in a wide range of cellular metabolic activities, including amino acid, lipid, and carbohydrate metabolism (Parra et al., 2018). The amount of pyridoxine in unoiled sumac samples varies between 72.2±3.8 - 244.2±9.2 µg /g dw. It was determined that the percentage loss of pyridoxine in unoiled samples varies between 32.0 - 46.2, while in oiled samples it varies between 15.0 - 28.6 (Table 5). The pyridoxine amount of Syrian and Chinese sumacs was reported to be 69.83 and 20.28 mg/kg, respectively (Kossah et al., 2009). It has been stated that the amount of pyridoxine in turmeric, black pepper and cloves were 22.61, 31.81 and 29.43 mg/100 g, respectively (Ayoade et al., 2023).

Folic acid helps in metabolism, nucleic acid synthesis, conversion of some amino acids into each other, protein metabolism, and supporting red blood cell formation and maturation (Schellack, 2015). While the amount of folic acid in oiled sumac samples varies between 414.3±15.0 to 726.1±21.5 µg /g dw, the percentage loss of folic acid compared to fresh samples varies between 11.2 and 15.2 (Table 5). In accordance with the findings of a previous study conducted by Ayoade et al. (2023), the levels of folic acid (B9) found in turmeric, black pepper, and cloves were reported to be 16.46 ± 0.03, 14.22 ± 0.02 and 15.81 ± 0.03 mg/100g, respectively.

Cyanocobalamin, which acts as a cofactor for enzymes in the metabolism of amino acids and fatty acids, is necessary for new cell synthesis, normal blood formation and neurological function (Halczuk et al., 2023). While the amount of cyanocobalamin in oiled samples varies between 72.2±4.0 - 134.2±6.0, in unoiled samples it is between 43.0±2.2 - 108.8±4.8 µg /g dw. Compared to fresh samples, loss of cyanocobalamin in oiled samples was found to be lower than in unoiled samples (Table 6).

The amount of Cyanocobalamin (B12) in Syrian and Chinese sumacs was reported to be 10.08±0.24 and 3.51±0.37 mg/kg, respectively (Kossah et al., 2009).

Ayoda et al. (2023) reported the amount of folic acid in ginger, garlic, turmeric, black pepper and gloves spices as 13.22, 11.23, 16.46, 14.22 and 15.81 mg/100 g, and the amount of vitamin B12 in the same samples as 10.64, 13.14, 12.84, 15.13, and 14.72 mg/100 g, respectively. Yamada et al.

(2008) reported that the shelf life of cyanocobalamin is affected by storage time, light exposure, and temperature.

Bakar et al. (2020) found that, the percentage losses of vitamins C, B1, B2, B3, B6, B9, B12 were 57.7, 47.33, 64.29, 47.26, 50.47, 55.58, 54, respectively in *Opuntia ficus-indica* fruit in sun dried samples. As a result of freezing of wild white *Myrtus communis* L. fruit, loss of ascorbic acid, thiamine, riboflavin, nicotine amide, pyridoxine, folic acid and cyanocobalamin was found to be 2.21, 3.43, 6.13, 3.37, 6.23, 1.16, 6.23 percent, respectively (Çakmak et al., 2021).

The amount of water-soluble vitamins in the oil-free and oil sumac groups in the same regions is statistically different ($p<0.05$). Karatas et al. (2017) reported that vitamin loss was less in oiled samples then unoiled red pepper flakes.

In this work, oiled and unoiled sumac samples water soluble vitamin contents reported and compared with the fresh sumac samples. It was observed that unoiled sumac samples vitamin contents decreased after six months in comparison with oiled and fresh sumac samples. On the other hand, vitamin loss of oiled sumac samples found to be less than unoiled sumac samples, showing that oiling of sumac is a good practice to reduce the vitamin loss.

The cause of difference in vitamin loss in sumac samples could be explained sample structure which is varies with region. It was observed that the amount of water-soluble vitamins in all sumac samples decreased significantly compared to fresh samples. However, vitamin loss in oiled samples were less than unoiled ones. The reason for the lower level of loss of vitamins in oiled samples might be explained by that the oiling partially prevents the oxidation of vitamins by forming a film layer on the surface of sumac particles.

4. Conclusion

Vitamin losses in oiled sumac samples are less than in unoiled samples. The amounts of vitamins in the oiled and unoiled samples are statistically different. From these results, it can be said that keeping sumac samples oiled for long term consumption is more advantageous to reduce the vitamin loss.

It can be concluded that water soluble vitamin content of unoiled sumac samples found to be higher when compared with fresh and oiled samples can be explained by oxidation. On the other hand, vitamin loss of oiled sumac samples was found less than unoiled sumac samples. For this reason, it is recommended to keep ground sumac samples oiled to minimize water-soluble vitamin losses.

Authors' Contributions

All authors contributed equally to the study.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The author declares that this study complies with Research and Publication Ethics.

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