

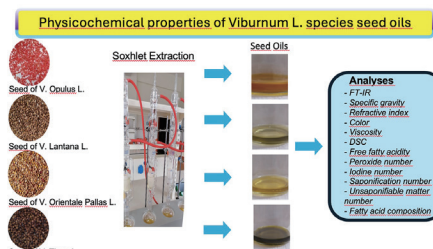
Physicochemical Properties of Medicinal and Aromatic *Viburnum* L. Species Seed Oils

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Abstract: The aim of this study is to determine the physicochemical properties of the seed oils of *Viburnum* L. species collected from different locations in Turkey over two consecutive years. For this purpose, *Viburnum opulus* L., *Viburnum lantana* L., *Viburnum orientale* Pallas and *Viburnum tinus* L. species growing naturally in Turkey were used. In this direction, the average values of *Viburnum* L. species seed oils in harvest years; specific gravity, refractive index, color, viscosity, boiling point, free fatty acidity, peroxide number, iodine number, saponification number and unsaponifiable matter number are; 0.92-0.93 g/cm³, 1.4760-1.4775 n_D, 4.20-10.70 (red), 2.40-70.00 (yellow), 63.90-75.57 mPa, 182.79-187.57°C, 0.74-1.36%, 10.38-17.82 meq O₂/kg, 117.35-134.18 wijs, 183.45-243.70 mg KOH/g, varied between 1.06-1.94%. The harvest year average values of palmitic acid, oleic acid, linoleic acid and linolenic acid contents of *Viburnum* L. species seed oils were determined as 1.99-8.95%, 29.33-57.95%, 35.43-55.98%, 0.17-0.50%, respectively. Also, seed oils were analyzed with FTIR and DSC. In line with these results, it was determined that the physicochemical properties of seed oils of *Viburnum* L. may vary depending on the species and harvest year and the obtained seed oils can be used as food supplement and vegetable oil in the food industry.



Key words: *Viburnum* L., seed oil, physicochemical, characterization, food

1 Introduction

It has been reported that the genus *Viburnum* consists of about 160 to 200 species, mostly small trees or shrubs, widely distributed in the temperate climate of the northern hemisphere, found in large clusters in Asia and Central America, and colonized in the southern hemisphere, usually in the mountainous regions of Southeast Asia and South America¹. In our country, it has been reported that there are four species, the majority of which are distributed in the Central Anatolia region, and these four species are: *Viburnum opulus* L., *Viburnum lantana* L., *Viburnum orientale* Pallas, *Viburnum tinus* L.^{2, 3}. It has been reported that *Viburnum* fruits are in the form of clusters consisting of 20-100 fruits and these fruits are yellow, orange, red, blue, purple and black in color according to the species when they complete their ripening⁴.

It has been reported that the fruits and juice of *V. opulus* are used to treat many diseases such as bleeding,

heart disease, high blood pressure, cough and colds, neurosis and diabetes⁵. *V. lantana* species was reported to be used as a painkiller in Turkish folk medicine⁶. *V. tinus* has been reported to have sedative and antispasmodic⁷ and antioxidant⁸ properties. Chlorogenic acid, a phytochemical component present in fruits, leaves and branches, has been shown to have antioxidant and enzyme-inhibiting properties in *V. orientale*⁹.

There is no data on concerning the use of *Viburnum* seeds other than *V. opulus*, which is one of the species utilized in Turkey's traditional fermented beverage production¹⁰. The pulp resulting from the production of this fermented beverage contains seeds rich in nutrients¹¹. It has been reported that these seeds contain 13.88% oil¹². Additionally, It was shown to have significant quantities of the unsaturated fatty acids oleic acid (45.7%) and linoleic acid (50.1%), as well as tocopherols α -tocopherol (110 mg/100 g), δ -tocopherol (60 mg/100 g) and to have high oxidative

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stability¹³⁾. Seed oils have attracted much attention in recent years due to their nutritional composition, oxidation stability and antimicrobial properties, as well as their health benefits such as immunity enhancement, blood cholesterol levels and positive properties on blood vessel walls¹⁴⁾.

The physicochemical characteristics of the seed oil of other species are unknown, despite the fact that research has been done on the seed oil of only the *V. opulus* species of the *Viburnum* genus^{10–12)}. The commercial importance of oils generally depends on various physical properties such as refractive index, color, specific gravity and viscosity. However, these physical properties are not sufficient for the characterization of oils. Therefore, other complex chemical properties such as acid value, free fatty acids, iodine value, peroxide value, melting point, color, fatty acid composition must also be known¹⁵⁾. In this context, this research aimed to reveal the physicochemical properties of seed oils of all *Viburnum* L. species grown in Turkey and to determine the usability of the oils in terms of vegetable oil technology and functionality.

2 Experimental Procedures

2.1 Materials

The seeds of *Viburnum* L. species were obtained from the fruits of *Viburnum* L. species collected consecutively two years. The natural distribution of *Viburnum* L. species in Turkey has been shaped under the influence of different climatic and soil conditions. Being able to reflect the real characteristics of the species is of critical importance in this study. For this reason, each *Viburnum* L. species was collected from different locations where it grows. Fruits of these species, *Viburnum opulus* L. were collected in October, from the Kayseri-Melikgazi 38° 42' 57.3" N 35° 42' 0.6.3" E coordinated location, *Viburnum lantana* L. was collected in August, from the Ankara-Yenimahalle 40° 06' 04.7" N 32° 46' 40.7" E coordinated location, *Viburnum orientale* Pallas was collected in September, from the Amasya-Taşova 40° 36' 58.1" N 36° 21' 02.1" E coordinated location, *Viburnum tinus* L. was collected in October, from the Balıkesir-Erdek 40° 29' 12.6" N 27° 46' 48.3" E coordinated location. The chemicals used and solvents such as *n*-hexane were purchased from Tekkim (İstanbul, Türkiye).

2.2 Oil extraction

The fruits collected from the specified coordinates were washed, and their seeds were separated from the fruit before being dried at room temperature (22°C). The dried seeds were ground to a particle size of less than 1 mm, and oil extraction was performed using the Soxhlet method with *n*-hexane to carry out the specified analyses. The oil

extraction process in the Soxhlet apparatus, set to an approximate temperature of 70°C, lasted for 8 hours. At the end of the process, the seed oils were separated from *n*-hexane using a rotary evaporator set to 40°C.

2.3 Functional groups analysis

Seed oil samples were analyzed with functional groups analysis by Fourier-transform Infrared (FTIR) Spectroscopy (IRAffinity-1S, Shimadzu Corporation, Kyoto, Japan) using spectra in the range of 850 cm⁻¹ to 4000 cm⁻¹ with 15 scans and 4 cm⁻¹ resolution¹⁶⁾.

2.4 Specific gravity

The specific gravity of the seed oils obtained in the study was determined according to the pycnometer TS 894 standard¹⁷⁾.

2.5 Refractive index

The refractive indexes of the seed oil samples were determined by Abbe refractometer. For this purpose, the seed oil samples taken with the help of a spatula were poured onto the prism of the refractometer and readings were made at 20°C¹⁸⁾.

2.6 Color

The color values of the seed oil samples were determined using a Lovibond tintometer and 1 inch measuring cuvettes according to the standard AOCS Cc-13e-92 method¹⁹⁾.

2.7 Viscosity

50 mL of the seed oil samples obtained in the study were placed in separate viscosity containers and their viscosities were measured with a Vibro (SV-10) viscometer at 22°C. Measurements were carried out by taking 3 different readings for each type of seed oil sample²⁰⁾.

2.8 Melting profile analysis using differential scanning calorimetry

To determine the thermal properties of the seed oil samples, the products were analyzed using a Perkin Elmer Differential Scanning Calorimeter (DSC) 4000. After the samples were weighed to a precision of 0.001 in tared aluminum containers (Perkin Elmer 02190041), the containers were closed in an airtight manner. An empty aluminum container was used for reference. It was applied under high purity nitrogen gas in a controlled manner with a temperature range between -15°C and 250°C²¹⁾.

2.9 Free fatty acidity

Free fatty acidity was analyzed by direct titration of seed oil samples with 0.1 N KOH using phenolphthalein indicator using method number 2.201²²⁾. The free fatty acidity (FFA) value obtained was calculated in terms of KOH/g oil.

2.10 Peroxide number

The peroxide number of the seed oil samples was determined by applying the method number 2.501⁽²²⁾. The results were calculated as meq O₂/kg oil.

2.11 Iodine number

The iodine numbers of the seed oil samples were determined by applying the method number 2.205⁽²²⁾. The principle of the applied method is based on the Wijs process.

2.12 Saponification number

The saponification numbers of the seed oil samples were determined according to AOCS 1a-64⁽²³⁾.

2.13 Unsaponifiable matter number

The unsaponifiable matter number analysis was performed according to the standard numbered TS 4963⁽²⁴⁾.

2.14 Fatty acid composition

The fatty acid composition of *Viburnum* L. species seed oils was determined by gas chromatography with the method specified by AOCS, with the brand name SHIMADZU GC-2025. Fatty acid methyl esters prepared by treating the oils with potassium hydroxide and *n*-Heptane were determined by gas chromatography⁽²⁵⁾.

Temperatures

Column: 180°C

Injection: 200°C

Detector: 200°C

Flow rates

Carrier gas (N₂): 30 mL/min

Fuel gas (H₂): 28 mL/min

Dry air: 220 mL/min

Injection amount: 1 µL

2.15 Statistical analysis

All analyses were repeated at least 3 times. Comparison

of measured characteristics was performed using one-way ANOVA and Tukey tests. Statistical analyses were completed using Minitab v.16.1⁽²⁶⁾.

3 Results and Discussion

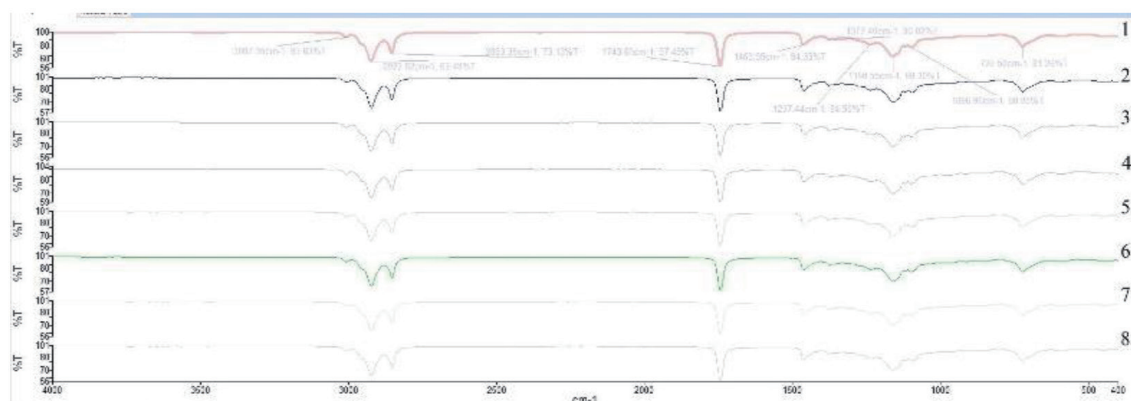
3.1 Fourier transform infrared

When the FT-IR spectrum in (Fig. 1) is examined, the peaks seen between 3007 cm⁻¹ and 3050 cm⁻¹ are the peaks belonging to aromatic groups⁽²⁷⁾. In addition, the peak seen at 722 cm⁻¹ shows the presence of aromatic structure in vegetable oils⁽²⁸⁾.

The peaks seen around 2853 cm⁻¹ and 2922 cm⁻¹ indicate asymmetric stretching vibrations belonging to aliphatic -C-H, -CH₃, -CH₂ groups⁽²⁹⁾. The vibration seen at 1743 cm⁻¹ is the stretching vibration of the functional groups of ester carbonyl (C=O) triglycerides⁽³⁰⁻³²⁾. The peaks seen at 1096 cm⁻¹ also belong to -C-O stretching vibrations. It can be said that this is caused by hydroxyl groups (OH)⁽³³⁻³⁵⁾. The peaks seen at 1160 cm⁻¹ and 1237 cm⁻¹ also indicate saturated aliphatic esters. The peak seen at 1463 cm⁻¹ is the C-H bending vibrations of -CH₂ and -CH₃ aliphatic groups⁽³⁶⁾. When the FT-IR findings obtained are analyzed, it is seen that the composition analyzed belongs to vegetable oils.

3.2 Physical properties

The physical properties of *Viburnum* L. species seed oils are shown in (Table 1). As shown in (Table 1), the average values of specific gravity of seed oils of *Viburnum* L. species were determined as *V. opulus* 0.92 g/cm³, *V. lantana* 0.93 g/cm³, *V. orientale* 0.93 g/cm³ and *V. tinus* 0.93 g/cm³. The specific gravity of seed oils of *Viburnum* L. species varied between 0.92 and 0.93 g/cm³ in both harvest years. There is no statistically significant difference ($p < 0.05$) between *Viburnum* L. species in terms of specific



1: *V. opulus* 2nd harvest year, 2: *V. opulus* 1st harvest year, 3: *V. lantana* 1st harvest year, 4: *V. lantana* 2nd harvest year
5: *V. tinus* 1st harvest year, 6: *V. tinus* 2nd harvest year, 7: *V. orientale* Pallas 1st harvest year, 8: *V. orientale* pallas 2nd harvest year

Fig. 1 FT-IR graphs of seed oils of *Viburnum* L. species.

Table 1 Physical properties of seed oils of *Viburnum* L. species.

Species	Harvest	Specific gravity (g/cm ³)	Refractive index (n _D)	Color (1 inch)		Viscosity (mPa)	Boiling Point (°C)
				Red	Yellow		
<i>Viburnum opulus</i> L.	1st year	0.92 ± 0.01 ^A	1.4762 ± 0.00 ^C	11.80 ± 0.00 ^A	70.00 ± 0.00 ^A	63.93 ± 0.38 ^C	185.66 ± 0.33 ^B
	2nd year	0.92 ± 0.01 ^a	1.4762 ± 0.00 ^c	9.60 ± 0.00 ^a	70.00 ± 0.00 ^a	63.87 ± 0.21 ^c	184.05 ± 1.09 ^{bc}
	Average	0.92 ± 0.00 ^X	1.4762 ± 0.00 ^X	10.70 ± 1.56 ^X	70.00 ± 0.00 ^X	63.90 ± 0.04 ^Y	184.86 ± 1.14 ^{XY}
<i>Viburnum lantana</i> L.	1st year	0.92 ± 0.01 ^A	1.4762 ± 0.00 ^C	2.80 ± 0.00 ^D	70.00 ± 0.00 ^A	69.00 ± 0.10 ^B	186.98 ± 0.88 ^A
	2nd year	0.93 ± 0.00 ^a	1.4782 ± 0.00 ^a	5.60 ± 0.00 ^c	70.00 ± 0.00 ^a	64.20 ± 0.27 ^c	188.15 ± 0.70 ^a
	Average	0.93 ± 0.01 ^X	1.4772 ± 0.00 ^X	4.20 ± 1.98 ^Y	70.00 ± 0.00 ^X	66.60 ± 3.39 ^{XY}	187.57 ± 0.83 ^X
<i>Viburnum orientale</i> Pallas	1st year	0.93 ± 0.01 ^A	1.4765 ± 0.00 ^B	4.40 ± 0.00 ^B	70.00 ± 0.00 ^A	68.33 ± 0.25 ^B	183.43 ± 0.22 ^C
	2nd year	0.92 ± 0.01 ^a	1.4755 ± 0.00 ^d	7.00 ± 0.00 ^b	46.00 ± 0.00 ^b	72.37 ± 0.15 ^b	182.14 ± 2.05 ^c
	Average	0.93 ± 0.01 ^X	1.4760 ± 0.00 ^X	5.70 ± 1.84 ^{XY}	58.00 ± 17.00 ^Y	70.35 ± 2.86 ^{XY}	182.79 ± 0.91 ^Y
<i>Viburnum tinus</i> L.	1st year	0.93 ± 0.01 ^A	1.4777 ± 0.00 ^A	4.20 ± 0.00 ^C	2.40 ± 0.00 ^B	74.67 ± 0.21 ^A	185.16 ± 0.25 ^B
	2nd year	0.92 ± 0.01 ^a	1.4773 ± 0.00 ^b	4.40 ± 0.00 ^d	2.40 ± 0.00 ^c	76.47 ± 0.25 ^a	186.10 ± 0.82 ^{ab}
	Average	0.93 ± 0.01 ^X	1.4775 ± 0.00 ^X	4.30 ± 0.14 ^Y	2.40 ± 0.00 ^Z	75.57 ± 1.27 ^X	185.63 ± 0.66 ^{XY}

± : Standard deviation; A-D: Statistical comparison of species within themselves in the 1st harvest year ($p < 0.05$ level) ; a-d: Statistical comparison of species within the selves in the 2nd harvest year ($p < 0.05$ level) ; X-Z: Statistical comparison of harvest year averages of species within themselves ($p < 0.05$ level) .

gravity in both harvest years. No study on the specific gravity of seed oils of *Viburnum* L. species was found in the literature. It has been reported that the specific gravity of seed oils of elderberry (*Sambucus canadensis* L.), which is in the same family as *Viburnum* L. species, obtained with different solvents varied between 0.932 and 0.952³⁷⁾. According to reports, oil extracted from *Moringa oleifera* seeds with varying moisture level at 30°C have specific gravities ranging from 0.90 and 0.97³⁸⁾. Furthermore, it has been observed that Roselle (*Hibiscus sabdariffa* L.) seed oil has a specific gravity of 0.955 to 0.958¹⁵⁾.

The average values of refractive index of seed oils of *Viburnum* L. species during harvest years were determined as 1.4762 n_D for *V. opulus*, 1.4772 n_D for *V. lantana*, 1.4760 n_D for *V. orientale* and 1.4775 n_D for *V. tinus*. The refractive index value varied between 1.4762 and 1.4777 n_D in the first harvest year and between 1.4755 and 1.4782 n_D in the second harvest year. There is a statistically significant ($p < 0.05$) difference between *Viburnum* L. species in terms of refractive index in both harvest years. In the first harvest year, the lowest refractive index was found in *V. opulus* species and the highest refractive index was found in *V. tinus* species. In the second harvest year, the lowest refractive index was found in *V. orientale* species and the highest refractive index was found in *V. lantana* species (Table 1).

No study was found in the literature on the refractive index of *Viburnum* L. species seed oils. According to a study, the refractive indices of the seed oils extracted from elderberry (*Sambucus canadensis* L.) seeds which belong to the same family as *Viburnum* L. species varied from 1.4696 to 1.4712³⁷⁾ when extracted using various solvents. According to a report, oils extracted from *Moringa oleifera* seeds with varying moisture percentages have viscosity values ranging from 43.50–44.30 kg/m³ at 40°C³⁸⁾. Furthermore, it has been observed Roselle (*Hibiscus sabdariffa* L.) seed oil viscosity to be 22.5 cp. at 28°C¹⁵⁾.

The color values of the seed oils of *Viburnum* L. species were determined by Lovibond tintometer as red (R) and yellow (Y) color values (Table 1). The harvest year averages of the red color values of *Viburnum* L. species seed oils were determined as 10.70 for *V. opulus*, 4.20 for *V. lantana*, 5.70 for *V. orientale* and 4.30 for *V. tinus*. The red color value varies between 2.80 and 11.80 in the first harvest year and between 4.40 and 9.60 in the second harvest year. There is a statistically significant difference between *Viburnum* L. species in terms of red color value in both harvest years. The species with the lowest red color value in the first harvest year is *V. lantana*, while the species with the highest is *V. opulus*. In the second harvest year, the lowest red color value was detected in *V. tinus*, while the highest red color value was detected in *V. opulus*, as in the first year.

The harvest year averages of the yellow color values of

Viburnum L. species seed oils were determined as 70.00 for *V. opulus*, 70.00 for *V. lantana*, 58.00 for *V. orientale* and 2.40 for *V. tinus*. In both harvest years, the yellow color value varies between 2.40 and 70.00. There is a statistically significant difference between *Viburnum* L. species in terms of yellow color value in the harvest year averages of *Viburnum* L. species seed oils. Considering this difference, it was observed that the yellow color values of the seed oils of *V. opulus*, *V. lantana* and *V. orientale* species were higher than *V. tinus* species.

No study has been found in the literature on the color values of seed oils of *Viburnum* L. species. However, examined the color values of elderberry (*Sambucus canadensis* L.) seed oil, which is in the same family with *Viburnum* L. species, and reported that the yellow color value varied between 2.5 and 29.8 and the red color value varied between 0.4 and 3.9 in *Sambucus canadensis* L. seed oil obtained with different solvents³⁷⁾. In a study they conducted on cold-pressed edible seed oils, reported the L*, a* and b* values of cranberry seed oil as 1.85, 2.55, 3.02, respectively, and the L*, a* and b* values of hemp seed oil as 0.93, 2.88, 1.44, respectively³⁹⁾.

The average viscosity values of the seed oils from *Viburnum* L. species for the harvest years were found to be 63.90 mPa for *V. opulus*, 66.60 mPa for *V. lantana*, 70.35 mPa for *V. orientale*, and 75.57 mPa for *V. tinus*. The viscosity value varies between 63.93 and 74.67 in the first harvest year and between 63.87 and 76.47 in the second harvest year (Table 1). There is a statistically significant difference between *Viburnum* L. species in terms of viscosity in both harvest years. While the species with the lowest viscosity in the first harvest year was *V. opulus*, the species with the highest viscosity was *V. tinus*. In the second harvest year, the viscosity values of *V. opulus* and *V. lantana* species were found to be lower than *V. orientale* and *V. tinus* species, and the highest viscosity value was observed in *V. tinus* species.

No study was found in the literature on the viscosity values of *Viburnum* L. species seed oils. Reported in a study that the viscosity values of the seed oils obtained with different solvents from elderberry (*Sambucus canadensis* L.) seeds, which are in the same family as *Viburnum* L. species, varied between 26.4 and 40.8 at 25°C³⁷⁾. It has been reported that the refractive indices of oils obtained from *Moringa oleifera* seeds with different moisture contents range between 1.457 and 1.460³⁸⁾.

The average boiling point values of the seed oils from *Viburnum* L. species for the harvest years were determined to be 184.86°C for *V. opulus*, 187.57°C for *V. lantana*, 182.79°C for *V. orientale*, and 185.63°C for *V. tinus* (Table 1). The boiling point values varied between 183.43°C and 186.98°C in the first harvest year and between 182.14°C and 188.15°C in the second harvest year. There is a statistically significant difference between *Viburnum* L. species

Table 2 Chemical properties of seed oils of *Viburnum* L. species.

Species	Harvest	Free fatty acidity (%)	Peroxide number (meq O ₂ kg ⁻¹)	Iodine number (wijs)	Saponification number (mg KOH g ⁻¹)	Non-saponifiable substance number (%)
<i>Viburnum opulus</i> L.	1st year	1.28 ± 0.10 ^B	16.40 ± 0.30 ^A	122.47 ± 1.89 ^B	210.10 ± 3.56 ^B	1.02 ± 0.08 ^C
	2nd year	0.76 ± 0.05 ^b	19.25 ± 0.34 ^a	124.12 ± 0.39 ^{bc}	254.80 ± 7.08 ^a	1.10 ± 0.32 ^{ab}
	Average	1.02 ± 0.37 ^X	17.82 ± 2.02 ^X	123.30 ± 1.17 ^{YZ}	232.45 ± 31.6 ^X	1.06 ± 0.06 ^X
<i>Viburnum lantana</i> L.	1st year	2.24 ± 0.24 ^A	11.64 ± 0.38 ^B	131.94 ± 1.52 ^A	190.10 ± 3.36 ^C	2.33 ± 0.22 ^A
	2nd year	0.48 ± 0.02 ^c	14.21 ± 0.26 ^c	136.42 ± 0.21 ^a	176.80 ± 4.28 ^c	1.54 ± 0.17 ^a
	Average	1.36 ± 1.25 ^X	12.93 ± 1.82 ^X	134.18 ± 3.17 ^X	183.45 ± 9.40 ^X	1.94 ± 0.56 ^X
<i>Viburnum orientale</i> Pallas	1st year	0.46 ± 0.04 ^C	10.33 ± 0.01 ^B	117.15 ± 0.30 ^C	220.40 ± 4.40 ^B	1.76 ± 0.15 ^B
	2nd year	1.01 ± 0.04 ^a	18.16 ± 0.41 ^b	117.54 ± 0.59 ^c	180.00 ± 6.56 ^c	0.96 ± 0.08 ^b
	Average	0.74 ± 0.39 ^X	14.25 ± 5.54 ^X	117.35 ± 0.28 ^Z	200.20 ± 28.60 ^X	1.36 ± 0.57 ^X
<i>Viburnum tinus</i> L.	1st year	1.40 ± 0.13 ^B	10.64 ± 0.91 ^B	129.19 ± 0.76 ^A	282.30 ± 7.45 ^A	2.26 ± 0.07 ^A
	2nd year	0.67 ± 0.04 ^b	10.12 ± 0.04 ^d	130.04 ± 8.13 ^{ab}	205.10 ± 4.29 ^b	0.76 ± 0.10 ^b
	Average	1.04 ± 0.52 ^X	10.38 ± 0.37 ^X	129.62 ± 0.60 ^{XY}	243.70 ± 54.6 ^X	1.51 ± 1.06 ^X

± : Standard deviation; A-C: Statistical comparison of species within themselves in the 1st harvest year ($p < 0.05$); a-d: Statistical comparison of species within themselves in the 2nd harvest year ($p < 0.05$); X-Z: Statistical comparison of harvest year averages of species within themselves ($p < 0.05$).

in terms of boiling points in both harvest years. In both harvest years, the species with the lowest boiling point was *V. orientale*, while the species with the highest boiling point was *V. lantana*. No study on the boiling points of *Viburnum* L. species seed oils was found in the literature. Reported that the melting curves of *V. opulus* seed oils were between 35.93 and 41.81°C and the melting curves of *V. opulus* seed oils extracted by ultrasound-assisted extraction (USEA), Soxhlet extraction (SE) and microwave-assisted extraction (MWAE) were 35.93°C, 35.99°C and 41.81°C, respectively¹⁰. In a study, the thermal behavior of raspberry and blackberry seed flour and oil was examined, and it was reported that the crystallization peak value of blackberry seed oil was -61.36°C, while the crystallization peak value of raspberry seed oil was -66.32°C⁴⁰.

3.3 Chemical properties

The chemical properties of seed oils of *Viburnum* L. species are shown in (Table 2). As indicated in (Table 2), the average values of free fatty acidity of seed oils of *Viburnum* L. species during harvest years were determined as follows; *V. opulus* 1.02%, *V. lantana* 1.36%, *V. orientale* 0.74%, *V. tinus* 1.04%. The amount of free fatty acidity varies between 0.46% and 2.24% in the first harvest year and between 0.48% and 1.01% in the second harvest year. There is a statistically significant difference between *Viburnum* L. species in terms of free fatty acidity in both harvest years.

In the first harvest year, the lowest free fatty acidity was observed in *V. orientale* species and the highest free fatty acidity was observed in *V. lantana* species. In the second harvest year, the lowest free fatty acidity was observed in *V. lantana* species and the highest free fatty acidity was ob-

served in *V. orientale* species.

Researchers investigated the changes of the seed oil of *V. opulus* species in natural conditions over a period of 11 months and reported that the acidity value varied between 7.2 mg KOH and 42.0 mg KOH during this period¹¹. In addition, the acidity value of *V. opulus* fruits was also investigated in a study and in this study, *V. opulus* fruits were collected at three maturity stages (1 month after flowering I; 2.5 months after flowering II; and 4 months after flowering III) and it was reported that the free fatty acidity value was 6.0% in maturity I, 1.2% in maturity II and 0.8% in maturity III⁴¹. In a study examining the chemical composition of the fractions of oil extracts obtained during supercritical extraction from strawberry (*Fragaria x ananassa* Duch), aronia (*Aronia melanocarpa* (Michx.)) and raspberry (*Rubus idaeus* L.) seeds, acid values were reported to vary between 1.4-10.9 mg KOH g⁻¹ in strawberry, 1.9-5.5 mg KOH g⁻¹ in aronia, and 7.0-20.6 mg KOH g⁻¹ in raspberry, respectively⁴². In addition to these studies, it has been reported that the acid values of oils obtained from *Moringa oleifera* seeds with different moisture contents range between 2.81 and 3.23 mg KOH g⁻¹³⁸. The results obtained were found to be slightly lower than literature data.

The average values of peroxide numbers of seed oils of *Viburnum* L. species in the harvest year were determined as 17.82 meq O₂/kg for *V. opulus*, 12.93 meq O₂/kg for *V. lantana*, 14.25 meq O₂/kg for *V. orientale*, 10.38 meq O₂/kg for *V. tinus*. Peroxide numbers varied between 10.33 meq O₂/kg and 16.40 meq O₂/kg in the first harvest year and between 10.12 meq O₂/kg and 19.25 meq O₂/kg in the second harvest year. There is a statistically significant difference between *Viburnum* L. species in terms of peroxide

numbers in both harvest years. According to this difference, the lowest peroxide number in the first harvest year was found in *V. orientale* species, and the lowest peroxide number in the second harvest year was found in *V. tinus* species. The highest peroxide number was found in *V. opulus* in both harvest years (Table 2).

In a study, the changes in the seed oil of *V. opulus* species under natural conditions over an 11 month period were examined, and it was reported that the hydroperoxide number in % active oxygen ranged between 0.018 and 0.090 during this 11 month period¹¹. In another study, oil was obtained from *V. opulus* seeds using three different extraction methods, and it was reported that the peroxide values of these oils were 6.24 meq/kg oil for ultrasound-assisted extraction, 7.45 meq/kg oil for microwave-assisted extraction, and 12.18 meq/kg oil for soxhlet extraction¹⁰. The results obtained were found consistent with these reported literature data. In another study examining the peroxide values of lipophilic extracts from *V. opulus* fruit pulp obtained by two extraction techniques, supercritical CO₂ (SFE-CO₂) extraction and soxhlet extraction (SE), it was reported that the peroxide values were 1.78 meq O₂/kg when the SFE-CO₂ technique was used, and 2.86 meq O₂/kg when the SE technique was used⁴³. In a study examining the chemical composition of the fractions of oil extracts obtained during supercritical extraction from strawberry (*Fragaria x ananassa* Duch), aronia (*Aronia melanocarpa* (Michx.)) and raspberry (*Rubus idaeus* L.) seeds, peroxide values were reported to vary between 2.7-25.7 meq O₂/kg in strawberry, 2.6-7.8 meq O₂/kg in aronia, and 0.9-7.6 meq O₂/kg in raspberry, respectively⁴². The fruits examined in this study belong to the same class as the *Viburnum* species used in our study, and while the peroxide values of strawberry samples were similar to the results we obtained, it was reported that the peroxide values of raspberry and aronia seed oils are lower.

The average values of iodine values of seed oils of *Viburnum* L. species in the harvest year were determined as 123.30 for *V. opulus*, 134.18 for *V. lantana*, 117.35 for *V. orientale*, and 129.62 for *V. tinus*. Iodine numbers vary between 117.15 and 131.94 in the first harvest year and between 117.54 and 136.42 in the second harvest year. There is a statistically significant difference between *Viburnum* L. species in terms of iodine counts in both harvest years. The lowest iodine number was found in *V. orientale* species and the highest iodine number was found in *V. lantana* species in both harvest years (Table 2).

The iodine number, a parameter used to determine the degree of unsaturation, is above 117 wijs in all species. This value is also related to the unsaturated fatty acid ratios of the species specified in Table 3. This is an indication that the seed oils of *Viburnum* L. have the potential to be used in various industries. There is no study in the literature that specifies the iodine numbers of *Viburnum* L. species

seed oils. In a study, it was reported that the iodine numbers of the seed oils of elderberry (*Sambucus canadensis* L.), which belongs to the same family as *Viburnum* L., obtained with different solvents, ranged between 161.98 wijs and 171.71 wijs³⁷. In another study, it was reported that the iodine content of oils obtained from *Moringa oleifera* seeds with different moisture contents ranged between 68.41 and 68.58 mg/100 g³⁸. The results obtained were found to be slightly lower than the elderberry sample and higher than the *Moringa oleifera* sample when compared to these studies reported in the literature.

The average values of saponification numbers of seed oils of *Viburnum* L. species in the harvest year were determined as 232.45 mg KOH/g for *V. opulus*, 183.45 mg KOH/g for *V. lantana*, 200.20 mg KOH/g for *V. orientale*, 243.70 mg KOH/g for *V. tinus*. Saponification numbers varied between 190.10 mg KOH/g and 282.30 mg KOH/g in the first harvest year and between 176.80 mg KOH/g and 254.80 mg KOH/g in the second harvest year. There is a statistically significant difference between *Viburnum* L. species in terms of saponification numbers in both harvest years. According to this difference, the species with the lowest saponification number in the first harvest year is *V. lantana* and the species with the highest saponification number is *V. tinus*. In the second harvest year, the species with the lowest saponification number was again *V. lantana*, but the species with the highest saponification number was *V. opulus* (Table 2).

No study was found in the literature indicating the saponification numbers of *Viburnum* L. species seed oils. In a study, it was reported that the saponification values of seed oils obtained from elderberry (*Sambucus canadensis* L.), which belongs to the same family as *Viburnum* L., with different solvents, ranged between 188.10 mg KOH/g and 257.00 mg KOH/g³⁷. The results obtained were consistent with literature data. In another study, the saponification values of oils obtained from *Moringa oleifera* seeds with different moisture contents were found to range between 91.16 mg KOH/g and 117.11 mg KOH/g³⁸. From the results we obtained, the data belonging to *Viburnum orientale* Pallas were consistent with the data of *Moringa oleifera*, while the data belonging to other species were higher. Additionally, in another study, the saponification values of blackberry and raspberry seed oils were reported to be 192.30 mg KOH/g and 188.59 mg KOH/g, respectively⁴⁰. The value ranges of saponification numbers obtained in our study were consistent with these data in the literature.

The harvest year average values of unsaponifiable matter counts in seed oils of *Viburnum* L. species were determined as 1.06% for *V. opulus*, 1.94% for *V. lantana*, 1.36% for *V. orientale*, and 1.51% for *V. tinus*. Unsaponifiable matter counts varied between 1.02% and 2.33% in the first harvest year and between 0.76% and 1.54% in the

Table 3 Fatty acid compositions of seed oils of *Viburnum* L. species.

Species/ Fatty acid (%)	<i>Viburnum opulus</i> L.		<i>Viburnum lantana</i> L.		<i>Viburnum orientale</i> Pallas		<i>Viburnum tinus</i> L.	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
Myristic acid (C14:0)	0.04 ± 0.01 ^C	0.07 ± 0.01 ^b	0.59 ± 0.02 ^A	0.06 ± 0.01 ^b	0.66 ^A ± 0.03	0.05 ± 0.01 ^b	0.22 ± 0.04 ^B	0.23 ± 0.01 ^a
	Avg: 0.06 ± 0.02 ^X		Avg: 0.33 ± 0.38 ^X		Avg: 0.36 ± 0.43 ^X		Avg: 0.23 ± 0.01 ^X	
Palmitic Acid (C16:0)	2.16 ± 0.03 ^D	1.82 ± 0.12 ^d	3.16 ± 0.10 ^C	3.03 ± 0.07 ^c	3.60 ± 0.01 ^B	3.75 ± 0.01 ^b	8.76 ± 0.17 ^A	9.14 ± 0.15 ^a
	Avg: 1.99 ± 0.24 ^Z		Avg: 3.10 ± 0.09 ^Y		Avg: 3.68 ± 0.11 ^Y		Avg: 8.95 ± 0.27 ^X	
Heptadecanoic Acid (C17:0)	0.05 ± 0.02 ^A	0.07 ± 0.03 ^a	0.05 ± 0.01 ^A	0.06 ± 0.02 ^a	0.03 ± 0.00 ^{AB}	0.04 ± 0.01 ^a	0.02 ± 0.00 ^B	0.02 ± 0.01 ^a
	Avg: 0.06 ± 0.01 ^X		Avg: 0.06 ± 0.01 ^{XY}		Avg: 0.04 ± 0.01 ^{XY}		Avg: 0.02 ± 0.00 ^Y	
Stearic Acid (C18:0)	0.58 ± 0.05 ^D	0.55 ± 0.03 ^c	1.74 ± 0.01 ^B	1.66 ± 0.06 ^b	1.66 ± 0.02 ^C	1.67 ± 0.01 ^b	2.97 ± 0.01 ^A	3.42 ± 0.08 ^a
	Avg: 0.57 ± 0.02 ^Z		Avg: 1.70 ± 0.06 ^Y		Avg: 1.67 ± 0.01 ^Y		Avg: 3.20 ± 0.32 ^X	
Arachidic Acid (C20:0)	0.23 ± 0.01 ^B	0.24 ± 0.01 ^b	0.06 ± 0.01 ^C	0.09 ± 0.01 ^c	0.07 ± 0.01 ^C	0.06 ± 0.01 ^c	0.65 ± 0.03 ^A	0.50 ± 0.11 ^a
	Avg: 0.24 ± 0.01 ^Y		Avg: 0.08 ± 0.02 ^Y		Avg: 0.07 ± 0.01 ^Y		Avg: 0.58 ± 0.11 ^X	
Behenic Acid (C22:0)	0.05 ± 0.01 ^C	0.11 ± 0.01 ^{bc}	0.14 ± 0.03 ^B	0.08 ± 0.01 ^c	0.06 ± 0.01 ^C	0.25 ± 0.01 ^a	0.42 ± 0.03 ^A	0.17 ± 0.05 ^b
	Avg: 0.08 ± 0.04 ^X		Avg: 0.11 ± 0.04 ^X		Avg: 0.16 ± 0.13 ^X		Avg: 0.30 ± 0.18 ^X	
Lignoceric Acid (C24:0)	0.25 ± 0.01 ^B	0.18 ± 0.04 ^b	0.60 ± 0.01 ^A	0.42 ± 0.02 ^a	0.07 ± 0.01 ^D	0.09 ± 0.01 ^c	0.15 ± 0.01 ^C	0.16 ± 0.01 ^b
	Avg: 0.22 ± 0.05 ^Y		Avg: 0.51 ± 0.13 ^X		Avg: 0.08 ± 0.01 ^Y		Avg: 0.16 ± 0.01 ^Y	
Total SFA	3.36 ± 0.04 ^Y	3.04 ± 0.22 ^z	6.34 ± 0.15 ^x	5.40 ± 0.04 ^y	6.15 ± 0.04 ^x	5.91 ± 0.05 ^x	13.18 ± 0.17 ^w	13.64 ± 0.14 ^w
Palmitoleic Acid (C16:1)	0.21 ± 0.02 ^A	0.16 ± 0.02 ^a	0.14 ± 0.00 ^{BC}	0.12 ± 0.03 ^a	0.10 ± 0.02 ^C	0.11 ± 0.01 ^a	0.18 ± 0.02 ^{AB}	0.19 ± 0.05 ^a
	Avg: 0.19 ± 0.04 ^X		Avg: 0.13 ± 0.01 ^X		Avg: 0.11 ± 0.01 ^X		Avg: 0.19 ± 0.01 ^X	
Oleic Acid (C18:1)	57.46 ± 0.27 ^A	55.73 ± 0.81 ^b	41.37 ± 0.31 ^B	38.33 ± 0.22 ^c	57.92 ± 0.09 ^A	57.98 ± 0.06 ^a	30.18 ± 0.03 ^C	28.48 ± 0.50 ^d
	Avg: 56.60 ± 1.22 ^X		Avg: 39.85 ± 2.15 ^Y		Avg: 57.95 ± 0.04 ^X		Avg: 29.33 ± 1.20 ^Z	
Eicosenoic Acid (C20:1)	0.03 ± 0.01 ^C	0.56 ± 0.01 ^a	0.15 ± 0.01 ^B	0.18 ± 0.01 ^c	0.12 ± 0.01 ^B	0.11 ± 0.01 ^c	0.73 ± 0.02 ^A	0.49 ± 0.05 ^b
	Avg: 0.30 ± 0.37 ^X		Avg: 0.17 ± 0.02 ^X		Avg: 0.12 ± 0.01 ^X		Avg: 0.61 ± 0.17 ^X	
Erucic Acid (C22:1)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Total MUFA	57.70 ± 0.28 ^w	56.45 ± 0.84 ^x	41.66 ± 0.31 ^x	38.63 ± 0.20 ^y	58.14 ± 0.05 ^w	58.20 ± 0.07 ^w	31.09 ± 0.03 ^y	29.15 ± 0.46 ^z
Linoleic Acid (C18:2)	38.79 ± 0.13 ^C	40.29 ± 1.49 ^b	51.51 ± 0.33 ^B	55.41 ± 0.10 ^a	35.35 ± 0.35 ^D	35.51 ± 0.37 ^c	55.17 ± 1.05 ^A	56.79 ± 0.06 ^a
	Avg: 39.54 ± 1.06 ^Y		Avg: 53.46 ± 2.76 ^X		Avg: 35.43 ± 0.11 ^Y		Avg: 55.98 ± 1.15 ^X	
Linolenic Acid (C18:3)	0.15 ± 0.01 ^D	0.18 ± 0.01 ^b	0.47 ± 0.03 ^B	0.52 ± 0.01 ^a	0.34 ± 0.02 ^C	0.35 ± 0.03 ^{ab}	0.53 ± 0.01 ^A	0.40 ± 0.21 ^{ab}
	Avg: 0.17 ± 0.02 ^Y		Avg: 0.50 ± 0.04 ^X		Avg: 0.35 ± 0.01 ^{XY}		Avg: 0.47 ± 0.09 ^X	
Total PUFA	38.94 ± 0.13 ^y	40.47 ± 1.49 ^x	51.98 ± 0.32 ^x	55.93 ± 0.09 ^w	35.69 ± 0.34 ^z	35.87 ± 0.41 ^y	55.69 ± 1.05 ^w	57.18 ± 0.15 ^w

±: Standard deviation; A-D: Statistical comparison of species within themselves in the 1st harvest year ($p < 0.05$); a-d: Statistical comparison of species within themselves in the 2nd harvest year ($p < 0.05$); X-Z: Statistical comparison of harvest year averages of species within themselves ($p < 0.05$); w-z: Statistical comparison of species within themselves in the both years in terms of total SFA, total MUFA and total PUFA amounts ($p < 0.05$); N.D.: Not detected; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

second harvest year (Table 2). There is a statistically significant difference between *Viburnum* L. species in terms of unsaponifiable substance counts in both harvest years. According to this difference, the species with the lowest unsaponifiable matter count in the first harvest year was determined as *V. opulus* and the species with the highest unsaponifiable matter count was determined as *V. lantana*. In the second harvest year, the species with the lowest unsaponifiable matter count was *V. tinus*, and the species with the highest unsaponifiable matter count was *V. lantana*.

There is no study in the literature indicating the unsaponifiable substance counts of *Viburnum* L. species seed oils. Reported in a study that the number of unsaponifiable substances of seed oils obtained with different solvents from elderberry (*Sambucus canadensis* L.) seeds, which

are in the same family as *Viburnum* L. species, varied between 1.48% and 4.00%³⁷⁾. The results obtained were consistent with literature data.

3.4 Fatty acid composition

The fatty acid compositions of the seed oils of *Viburnum* L. species are shown in Table 3. As seen in Table 3, when the fatty acid composition of the seed oils of *Viburnum* L. species was examined; it was determined that in *V. opulus* and *V. orientale* Pallas species, oleic acid constituted the highest fatty acid ratio in both years, followed by linoleic acid and palmitic acid, respectively, while in *V. lantana* and *V. tinus* species, linoleic acid constituted the highest fatty acid ratio in both years, followed by oleic acid and palmitic acid, respectively. Apart from these fatty acids, it was determined that the other 10 fatty acids speci-

fied in (Table 3) were also contained in certain proportions, and erucic acid was not found in the seed oils of *Viburnum* L. species.

Harvest year averages of some fatty acids in seed oils of *Viburnum* L. species, from most to least; oleic acid (56.60%), linoleic acid (39.54%), palmitic acid (1.99%), linolenic acid (0.17%) for *V. opulus*, linoleic acid (53.46%), oleic acid (39.85%), palmitic acid (3.10%), linolenic acid (0.5%) for *V. lantana*, oleic acid (57.95%), linoleic acid (35.43%), palmitic acid (3.68%), linolenic acid (0.35%) for *V. orientale* Pallas, linoleic acid (55.98%), oleic acid (29.33%), palmitic acid (8.95%), linolenic acid (0.47%) for *V. tinus*. The highest proportion of total saturated fatty acids was observed in the *V. tinus* species. When looking at the unsaturated fatty acids, the highest total monounsaturated fatty acid content was found in *V. orientale* Pallas, while the highest total polyunsaturated fatty acid content was detected in *V. tinus*, followed by *V. lantana*. The high oleic acid content and number of double bonds in the species indicate that they could be a valuable source of oil.

In a study, the fatty acid composition of free lipids obtained from *V. opulus* seeds was examined during storage under natural conditions, and it was reported that oleic acid (41.8%) and linoleic acid (47.6%) were the most abundant fatty acids, although some changes occurred during the storage process. In another study, the fatty acid composition of *V. opulus* seed oil extracted by MWAE, USAE, and SE was examined, and it was found that the highest fatty acid content was oleic acid. The proportion of oleic acid was determined to be 54.15% in microwave-assisted extraction, 53.72% in ultrasound-assisted extraction, and 53.04% in Soxhlet extraction. The second highest fatty acid content was linoleic acid, with proportions of 32.67% in Soxhlet extraction, 31.53% in microwave-assisted extraction, and 29.53% in ultrasound-assisted extraction¹⁰⁾.

Although there is no study in the literature on the fatty acid composition of seed oils of species other than *V. opulus*, these values specified for *V. opulus* species are parallel to the values obtained in our study. Apart from these studies, the fatty acid composition of the fractions of oil extracts obtained from strawberry, aronia, and raspberry seeds through supercritical extraction method has been investigated. As a result of this study, they reported that strawberry seed oil had linoleic acid between 47.9-48.7% and alpha linolenic acid between 29.7-31.7%, aronia seed oil had linoleic acid between 68.8-72.9% and oleic acid between 16.4-18.0%, and raspberry seed oil had linoleic acid between 48.0-48.7% and alpha linolenic acid between 36.1-38.0%⁴²⁾.

The fatty acid compositions of the oils of six cold-pressed fruit seeds were investigated and as a result of this study, in blackberry seed oil 19.1-19.5% oleic acid, 49.4-51.0% linoleic acid, 16.6-17.4% alpha linolenic acid; rasp-

berry seed oil 14.9-15.6% oleic acid, 43.6-45.6% linoleic acid, 29.2-29.6% alpha linolenic acid, blueberry seed oil 20.8-21.2% oleic acid, 37.9-42.9% linoleic acid, 24.3-30.3% alpha linolenic acid, strawberry seed oil 15.7-16.0% oleic acid, 38.9-46.0% linoleic acid, 35.0-36.3% alpha linolenic acid, blackcurrant seed oil 14.4-15.1% oleic acid, 45.2-47.7% linoleic acid, 11.8-13.2% alpha linolenic acid, sea buckthorn seed oil 15.4-22.9% oleic acid, 35.4-38.9% linoleic acid, 29.8-36.3% alpha linolenic acid were detected⁴⁴⁾.

According to the obtained physicochemical results and literature comparisons of *Viburnum* L. species seed oils; it was determined that FTIR results have chemical groups compatible with vegetable oils. On the other hand, it was seen that all species seed oils have the properties of crude vegetable oils in terms of specific gravity, refractive index, color, viscosity, boiling points, free fatty acidity, peroxide number, saponification, unsaponifiable matter amount and fatty acid composition, bitterness, oxidation, some technical specifications required for refining process.

4 Conclusion

In line with these results; It was determined that, except for the specific gravity and FTIR results, all other determined properties of the physicochemical properties of the seed oils of *Viburnum* L. species varied statistically according to the harvest year and location, that the seed oils were suitable for use in terms of the results determined, that the obtained specifications were usable in terms of vegetable oil technology and that they could show functional properties especially in terms of fatty acids composition. In addition, it was determined that the results obtained will be the first to enter in terms of especially three types for seed oils of certain *Viburnum* L. species, for disciplines other than food science (chemistry, pharmacology, etc.). The data obtained show that it fills an important gap in the literature on this subject. In future studies, it is recommended to determine the phytochemical properties of seed oils obtained from these species.

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Author Contributions

Authors' contributions are equal in all stages of planning, execution and completion of the study.

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