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Comprehensive characterization of physicochemical, thermal, compositional, and sensory properties of cold-pressed rosehip seed oil

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SUMMARY: In this study, cold-pressed rosehip seed oil was fully characterized. Acidity and oxidation levels were near the limit values or slightly exceeded them and improvement in the storage conditions was suggested. The oil started to crystallize at -45.25 °C, and melt at -25.56 °C. Linoleic acid (51.1%), β-sitosterol (84.6%), γ-tocopherol (773.76 µg/g) and rosmarinic acid (31.38 µg/g) were determined as major fatty acid, sterol, tocopherol and phenolic compound, respectively. For the first time, aromatic volatile compounds and sensory descriptive terms were determined for cold-pressed rosehip seed oil. Sixty-seven volatile compounds were detected and L-limonene was found to be a major volatile compound. According to the sensory analysis, timber/kindling and raw vegetable tastes/aromas were found to be relatively dominant. Consequently, it is thought that rosehip seeds can be used as a raw material for edible and nutritionally-rich cold-pressed oil production and/or as source oil for functional food preparations.

KEYWORDS: *Cold-Press; Composition; Physicochemical Property; Rosehip Seed; Sensorial Description; Volatile Compound*

RESUMEN: ***Caracterización integral de las propiedades fisicoquímicas, térmicas, composicionales y sensoriales del aceite de semilla de rosa mosqueta prensado en frío.*** En este estudio se caracterizó completamente el aceite de semilla de rosa mosqueta prensado en frío. Los niveles de acidez y oxidación estaban cerca de los valores límite o los excedían ligeramente y se sugirió mejorar las condiciones de almacenamiento. El aceite comenzó a cristalizar a -45,25°C y a fundirse a -25,56°C. Se determinó el ácido linoleico (51,1%), β-sitosterol (84,6%), γ-tocoferol (773,76 µg/g) y ácido rosmarínico (31,38 µg/g) como principal ácido graso, esterol, tocoferol y compuesto fenólico, respectivamente. Por primera vez, se determinaron compuestos aromáticos volátiles y términos descriptivos sensoriales para el aceite de semilla de rosa mosqueta prensado en frío. Se detectaron sesenta y siete compuestos volátiles y se descubrió que el L-limoneno era un compuesto volátil importante. Según el análisis sensorial, se encontró que los sabores/aromas de madera/astillas y vegetales crudos eran relativamente dominantes. En consecuencia, se cree que las semillas de rosa mosqueta pueden usarse como materia prima para la producción de aceite prensado en frío comestible y nutritivo y/o como aceite fuente para preparaciones de alimentos funcionales.

PALABRAS CLAVE: *Composición; Compuestos volátiles; Descripción Sensorial; Prensado en frío; Propiedades fisicoquímicas; Semilla de rosa mosqueta*

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1. INTRODUCTION

Rosehip (*Rosa canina* L.) is a plant from the Rosaceae family with more than 200 species and approximately 18000 varieties in the world. Rosehip plant is rarely affected by environmental conditions, and can grow on infertile soils with a harsh climate. It spreads naturally in Asia, Caucasia, Europe, and Africa. It is a 2-3-meter tall plant in the form of a bush. Its flowers can be of different colors, from white to pink. Rosehip plant has 3-15 leaves, which are mostly green and sometimes slightly bluish in color with a drop-shaped and hairless structure. Rosehip fruits are round, egg-shaped or elliptical and their colors vary from orange to red. There are about 20-30 hairy and hard-shelled seeds inside the fruit. Although it varies according to the rosehip type, generally, the harvest begins in July and continues until mid-November (Türkben, 2003; BUGEM, 2020).

According to the Ministry of Agriculture and Forestry of Turkey, the annual rosehip production was 195 tons in 2014, and 3783 tons in 2018. In 2019, cultivated production was 998 tons and 113.4 tons were collected from nature. The farmers were promoted by the ministry for more production (BUGEM, 2020). The global rosehip oil market value was predicted as 141 million dollars in 2021, and projected to reach 275.6 million dollars in 2028. Further, the oil was estimated to be segmented mostly in skin and hair care products, and predicted to extend into other functional preparations (Anonymous, 2023).

Worldwide, rosehip fruit is generally consumed as jam, marmalade, and tea. During the processing of rosehip fruit into these products, generally, rind and seeds are removed as wastes. Rosehip seeds, which are between 30 and 40% by weight in fresh fruit and removed a waste during the processing of rosehips, are not adequately utilized. The seeds have been used in the cosmetic and pharmaceutical industries in recent years (Göknur, 2013; Çağlar and Demirci, 2017). The composition of rosehip seeds was reported as 1.94–2.09% ash, 6.89–8.64% protein, and 6.92– 8.60% oil (Kadakal, 2002). In a recent review (Mannozzi *et al*., 2020), different studies in the literature showed that rosehip seeds contain around 1.2–3.9% ash, 3.0–11.5% protein, 6.3–17.8% oil, and 40.0–89.0% carbohydrates, including fiber.

Since significant amounts of seed are obtained as a waste during rosehip processing, concern about valorizing them has been raised. In particular, the oil contained in the seeds received attention from researchers and producers (Barros *et al*., 2011; Güneş *et al*., 1027; Dabrowska *et al*., 2019; Mannozzi *et al*., 2020). The above-cited literature indicated that rosehip oil contains approximately 3.0-8.0% palmitic, 1.5-3.5% stearic, 13.0-23.0% oleic, 35.0-56.0% linoleic, and 14.0-35.0% linoleic acid as major fatty acids. The variation seems to be due to different varieties, regions and climates, but generally the oil seems to be unsaturated and essential fatty acid rich. Further, the oil was shown to contain 5.29 mg/100 g total tocopherol, of which 3.47 mg was γ-tocopherol (Barros *et al*., 2011). Also, the main sterol in rosehip oil was β-sitosterol, and the presence of brassicasterol, campesterol, stigmasterol, Δ-5- and Δ-7-avenasterol was reported (Mannozzi *et al*., 2020). Therefore, rosehip oil is rich in bio-active substances such as essential fatty acids, phytosterols, tocopherols, and carotenoids, and it might have functional uses as anti-inflammatory, anti-obesity, anti-oxidant, anti-diabetic, skin care, and others in culinary applications, cosmetics, and pharmaceutical industries (Barros *et al*., 2011; Göknur, 2013; Mannozzi *et al*., 2020).

Considering that rosehip seed oil is rich in bioactive compounds, it is thought that rosehip seeds can be used in the production of gourmet oil. Cold pressing is a very suitable technique for gourmet oil production like rosehip seed oil. The cold-press technique yields clean, sensorially acceptable, and high-quality oils and by this technique all the naturally present bioactive compounds are preserved (Aydeniz *et al*., 2014).

In this study, the aim was to characterize cold-pressed rosehip seed oil. Physicochemical, thermal, compositional, and sensorial properties of the oil were determined. Some data (composition of aromatic volatiles and sensory properties) were presented for the first time for those interested in utilizing this special oil. Hence, possible uses for this new oil would be foreseen.

2. MATERIALS AND METHODS

2.1. Materials

The cold-pressed rosehip seed oil used in this study was purchased from Bade Natural (Istanbul, Turkey). The company informed us that the rosehip seeds used in the oil production were obtained from rosehip fruit harvested in the Gümüşhane region of Turkey in November 2020, and the cold-pressed oil was generated

in June, 2021. The oil analyses started in our laboratory in December, 2021. Therefore, the oil was stored for almost 6 months under premium conditions before the analyses took place. All chemicals, solvents, and standards used in the analyses were of analytical or chromatographic grade and purchased from Sigma (St. Louis, MO, USA) and Merck Co. (Darmstadt, Germany). Cold-pressed rosehip seed oil is shown in Figure 1.

FIGURE 1. Cold-pressed rosehip seed oil

2.2. Physicochemical properties of the oil

Specific gravity was determined according to the AOCS Cc 10b-25 method (AOCS, 2017), specific extinction values were measured with a spectrophotometer (Shimadzu UV-1800, Shimadzu Co., Kyoto, Japan) according to the AOCS Ch 5-91 method (AOCS, 2017), and refractive index was determined by an Abbe 5 refractometer (Bellingham and Stanley, Tunbridge Wells, UK). Apparent viscosity was measured by a Brookfield DV II + Pro Viscometer (Brookfield Eng. Lab., Inc., Middleborough, MA, USA) with LV-SC4-18 spindle and 50-rpm rotation speed at room temperature. Color values (L, a*, and b*) were measured with a Minolta colorimeter CR-400 (Konica, Minolta Sensing, Osaka, Japan).

Free fatty acidity, peroxide value, *p*-anisidine value, iodine number, saponification number and unsaponifiable matter contents were measured according to AOCS Ca 5a-40, AOCS Cd 8b-90, AOCS Cd 18-90, AOCS Cd 1b-87, AOCS Cd 3-25, and TSE 894, respectively (TSE, 1970; AOCS, 2017). The total phenolic content and antioxidant capacity of the oil were determined according to Aydeniz *et al*. (2014) with an Agilent 8453 UV–Vis Spectrophotometer (Waldbronn, Germany). The total carotenoid content of the oil was measured according to Franke *et al.* (2010) by using an Agilent 8453 UV–Vis Spectrophotometer (Waldbronn, Germany).

2.3. Thermal analyses of the oil

The thermal properties of the oil were measured with a differential scanning calorimeter (DSC, Perkin-Elmer DSC 4000, Waltham, MA). Melting and crystallization parameters of the oil were determined according to Aydeniz *et al.* (2014). A 5–10 mg sample was placed into an aluminum pan, sealed hermetically, and analyzed against an empty pan. The thermal program was as follows: heating from 20 to 110 °C at a rate of 10 °C/min; cooling from 110 to −40 °C at a rate of 10 °C/min; holding at that temperature for 3 min and then heating from −40 to 50 °C at a rate of 5 °C/min. Nitrogen (99.99%) was used during analysis. The thermal parameters were calculated with Pyris 1 Manager Software.

The oxidative induction time (OIT) of the oil was determined according to Aydeniz *et al.* (2014). A 5-10 mg sample was placed into an aluminum pan and analyzed against an empty pan. The thermal program was as follows: heating from 30 to 170 °C at a rate of 50 °C/min with nitrogen (99.99%) and holding at that temperature for 30 min with oxygen (99.99%). The OIT of the oil was calculated with Pyris 1 Manager Software.

2.4. Determination of the fatty acid, sterol, and tocopherol compositions

The fatty acid composition of the oil was determined according to TGK 2017/26 (2017). First, fatty acid methyl esters (FAME) were prepared. 100 mg of the oil were dissolved into 2 ml heptane. Then, 0.2 ml of 2 M methanolic KOH were added and the mixture was vortexed for 30 s. Finally, the mixture was centrifuged at 6461 xg for 5 min (Sigma 2-16K, Sartorius, Germany) and the clear phase was taken into a vial for injection. The fatty acid composition was determined by a Gas Chromatograph-FID (Agilent Technologies 7890B, Palo Alto, CA, US) with a HP 88 capillary column (100 m × 0.25 mm ID × 0.2 μm

film thickness, J&W Scientific Co., CA, USA). The injection volume was 0.2 µl and the injector split ratio was 1:10. Hydrogen was used as carrier gas at a flow rate of 1.7 ml/min. Hydrogen (40 ml/min) and dry air (450 ml/min) were detector gases. The inlet temperature was 250 °C and detector temperature was 280 °C. The oven temperature program was as follows: holding at 130 °C for 1 min, heating to 170 °C at a rate of 6.5 °C/min, heating to 215 °C at a rate of 2.75 °C/min and holding at that temperature for 12 min, then heating to 230 °C at a rate of 40 °C/min, holding at that temperature for 5 min. Fatty acids were identified by using a FAME standard mixture (37-components, 4-24, Supelco, Bellefonte, PA, USA).

The sterol composition was determined according to the TSE EN ISO 12228 method (TSE, 1999). First, the unsaponifiable matters were obtained, and then the sterol fractions were separated with Thin Layer Chromatography (TLC). The sterol composition was determined by Gas Chromatograph-FID (Agilent Technologies 7890B) with a DB5 capillary column (30 m × 0.25 mm ID × 0.1 µm film thickness, J&W Scientific Co). Injection volume was 1 µl and the injector split ratio was 1:100. Hydrogen was used as carrier gas at a flow rate of 0.7 ml/min. Hydrogen (30 ml/min) and dry air (400 ml/min) were detector gases. The inlet temperature was 290 °C and detector temperature was 300 °C. The oven temperature program was as follows: holding at 60 °C for 2 min, heating to 220 °C at a rate of 40 °C/min and holding at that temperature for 1 min, then heating to 310 °C at a rate of 5 °C/min, then holding at that temperature for 30 min. The sterols were identified using commercial standards.

Tocopherol composition was determined according to Grilo *et al*. (2014) with minor modifications. 0.5 ml oil were diluted to 5 ml with dichloromethane and analyzed by a HPLC (Shimadzu Co., Kyoto, Japan) with Inertsil SIL 100A column (250 mm× 4.6 mm× 5 µm, GL Sciences Inc., Japan) and a RF-20A fluorescent detector. A methanol:water (97:3, v/v) mixture was used as the mobile phase. Isocratic elution was used with 0.8 ml/min flow rate. Detector wavelengths were 290 and 330 nm for excitation and emission, respectively. Commercial standards were used for the identification and quantification of the tocopherols.

2.5. Determination of phenolic compounds in the oil

Approximately 3 g of oil were dissolved into 3 ml of hexane, and then 3 ml of methanol were added. After that, the mixture was centrifuged at 6461 xg for 3 minutes (Sigma 2-16K, Sartorius, Germany) and the supernatant was collected. This process was repeated three times. Then, the methanolic phase was evaporated, the residue was dissolved in 1 ml of methanol and placed into a vial for injection. The phenolic composition of the oil was analyzed by a HPLC (Shimadzu Co., Kyoto, Japan) equipped with an Agilent Eclipse XDB-C18 column (250 mm × 4.6 mm × 5 µm) and a SPD-M20A diode array detector (λmax=278nm). Acetic acid:water (3:97, v:v) (A) and methanol (B) were used as the mobile phases and flow gradients used in this analysis were as follows: 0. min 0% A, 0.1–18 min 80% A, 18–24 min 70% A, 24–30 min 67.5% A, 30–36 min 45% A, 36–40 min 0% A, 40–45 min 60% A, and 45–47 min 80% A. Column temperature was 30 °C, flow rate was 0.8 ml/min and the injection volume was 20µl. Commercial standards (Sigma-Aldrich and Fluka Chem Co., St. Louis, MO, USA) were used for the identification and quantification of the phenolic compounds.

2.6. Determination of aromatic volatile compounds in the oil

The aromatic volatile compounds in the oil were determined according to Aydeniz *et al*. (2014). First, 2 g of oil were placed into an amber-colored vial and the vial was kept in a water bath at 60 °C for 30 min. Then, the volatile compounds collected at the headspace of the vial were taken with the SPME fiber coated with 75 µm carboxen/polydimethylsiloxane coating. GC-MS (Shimadzu 2010 SE) with a Restek Rtx-5Sil MS column (30 m x 0.25 mm, 0.25 µm, Fisher Scientific International, Inc., USA) was used to determine the volatile compounds. Helium was used as carrier gas with 1.61 ml/min flow rate. Injector and detector temperatures were set to 250 °C, and 70 eV ionization energy was used. The temperature program was as follows: holding at 40 °C for 2 min and heating to 250 °C at a rate of 4 °C/min. For the identification of compounds, The National Institute of Standards and Technology and Wiley Registry of Mass Spectral Data were used.

2.7. Sensory descriptive analysis of the oil

A sensory descriptive analysis of the oil was carried out through Quantitative Descriptive Analysis (QDA) (Meilgaard *et al*., 1991). There were six female and six male trained panelists aged between 21 and 52. These panelists were trained for at least 10

Table 1. Descriptive terms and references used in the sensory descriptive analysis

Descriptor	Definition	Reference
Spicy	Aroma perceived from spice blends	Aqueous solution of red pepper-black pepper-thyme
Earthy	The odor detected from moist soil	Wet soil
Timber/Kindling	The odor perceived from the dry wood	Pieces of wood and kindling, toothpick
Raw Vegetable	The flavor of raw vegetables	Fresh green beans
Bitter	Basic taste of caffeine and quinone	0.05% caffeine solution (full bitter)

hours on different days and in different sessions. Under the management of the panel leader, five different sensory terms were developed to describe cold-pressed rosehip seed oil. The descriptive terms and references used in this analysis are presented in Table 1. Samples were served in glasses at room temperature. A 10 cm line scale from 1 at minimum intensity to 10 at maximum intensity was used to quantify the sensory characteristics. Water, unsalted cracker, dry coffee, and expectoration cups were provided to panelists in addition to the samples.

2.8. Statistical analysis

Two different cold-pressed rosehip seed oil samples from the same production year were obtained. Each analysis for each sample was made at least in duplicate, or in triplicate. The results of the sensory analysis are presented as means with standard deviation. All other data are presented as means with standard errors.

3. RESULTS AND DISCUSSION

3.1. Physicochemical properties of the oil

The physiochemical properties of the cold-pressed rosehip seed oil are presented in Table 2. Specific gravity and refractive index values depend on the fatty acid compositions of oils and vary according to the oil type. In a study about rosehip seed oil, the specific gravity value was found to be 0.927 at 20 °C (Concha *et al.,* 2006). The refractive index value of rosehip seed oil was measured as 1.481 and 1.478 in the studies of Concha *et al.* (2006) and Nino *et al.* (2020), respectively. Our results concur with the literature.

The viscosity of the sample at 25 °C was determined as 49.5 cP. In a study (Milic *et al.,* 2020), the viscosity of cold-pressed rosehip seed oil was measured as 89.4 cP at 20 °C. The viscosity value of the oil sample did not exactly match with the literature,

Table 2. Physicochemical properties of the oil

Property	Value
Specific gravity (25 °C)	0.92 ± 0.01
Specific extinctions	
E232	3.76 ± 0.15
E270	2.84 ± 0.01
Refractive index (25 °C)	1.48 ± 0.00
Viscosity (25 °C, cP)	49.50 ± 0.30
Color	
L	22.96 ± 0.01
a*	0.93 ± 0.02
b*	2.26 ± 0.01
Free fatty acids (linoleic acid %)	1.61 ± 0.07
Acid value (mg KOH/g oil)	3.22 ± 0.14
Peroxide value (meqO_2/kg oil)	14.54 ± 0.91
p-Anisidine value	3.35 ± 0.10
Iodine value (g I_2/100 g oil)	170.04 ± 2.54
Saponification value (mg KOH/g oil)	193.47 ± 2.22
Unsaponifiable matter (%)	1.37 ± 0.04
Total phenolic content (mg GA/100 g)	20.33 ± 1.07
Total carotenoid (mg/kg)	46.50 ± 0.90
Antioxidant capacity (μmol TE/g)	1.43 ± 0.02

Results are expressed as mean ± SE. Each analysis was done at least in duplicate, or in triplicate

probably due to differences in the measurement temperature and genotype of the rosehip seeds. The L, a*, and b* color values are presented in Table 2. There is no data in the literature for comparison. As seen in Figure 1, the oil is dark orange in color which matches with the measured color values.

The free fatty acidity and acid values are shown in Table 2. According to the codex, the acid value should be a maximum of 4.0 mg KOH/g oil for cold-pressed oils (Codex, 2012). Therefore, it can be said that the acid value of the sample was near the limit value but within acceptable limits. Peroxide and

p-anisidine values are used to determine primary and secondary oxidation products, respectively. According to codex, the limit for the peroxide value for cold-pressed oils is 15 meqO_2/kg oil (Codex, 2012). The peroxide value of the oil was near the limit value but within acceptable limits. The peroxide value for cold-pressed rosehip seed oil was measured as 1.2 and 2.1 meqO_2/kg oil in the studies of Grajzer *et al*. (2015) and Tenekeci (2017), respectively. These peroxide values are much lower than the value in our study. In our study, the *p*-anisidine value was measured as 3.35. In a study by (Grajzer *et al*., 2015), *p*-anisidine values for cold-pressed rosehip oils from two different manufacturers were found to be 2.5 and 7.7. Specific extinction values at 232 and 270 nm are the indicators of primary and secondary oxidation products. According to codex, E232 and E270 values for extra virgin olive oil should be a maximum of 2.50 and 0.22, respectively (Codex, 2017). Oil types are different, but production techniques are similar; therefore, these limit values could be suitable for comparison. The oil sample in this study exceeded the limit values given in codex. Oxidation probably occurred during the storage of the seeds (before cold pressing) and during the cold-pressing process. Therefore, storage conditions should be improved.

Iodine number and saponification values are parameters which vary according to oil type. The iodine number and the saponification value for the cold-pressed rosehip oil were determined as 170.04 g I_2/100 g oil and 193.47 mg KOH/g oil, respectively. In some studies (Grajzer *et al*., 2015; Milic *et al.,* 2020), the iodine number of the cold-pressed rosehip oil was measured as 160 and 157.8 g I_2/100 g oil. The saponification value was determined as 187.4 mg KOH/g oil in the study by Concha *et al.* (2006) and 184.2 mg KOH/g oil in the study by Milic *et al.* (2020). Although there are some slight differences, our results generally concur with the literature.

In this study, the unsaponifiable matter content in the cold-pressed rosehip seed oil was determined as 1.37%. In one study (Concha *et al.,* 2006), the unsaponifiable matter content in the rosehip seed oil was found to be 1.4%. Our result concurs with the literature. Total phenolic content and total carotenoid content are shown in Table 2. It is known that phenolic compounds have various health effects and affect the sensory properties of oils (Gioxari *et al.,* 2016). The total phenolic content in rosehip seed oil was measured as 21.54 mg GA/100 g in one study (İlyasoğlu, 2014) and 31.08 mg GA/100 g in another study (Demir *et al.,* 2014). The results from this study generally concur with the literature. In this study, the total carotenoid content in the cold-pressed rosehip seed oil was measured as 46.5 mg/kg. In one study (Fromm *et al.,* 2012), the total carotenoid content in rosehip seed oil was found to be 39.15 mg/kg; while in another study (Grajzer *et al.,* 2015), it was determined as 36.4 mg/kg. It was observed that the carotenoid content in the sample was slightly higher, possibly due to variety or region.

The antioxidant capacity of the oil is shown in Table 2. In some studies, the antioxidant capacity of rosehip seed oil was determined as 1.77 µmol TE/g (İlyasoğlu, 2014), 2.53 µmol TE/g (Grajzer *et al.,* 2015), and 1.69 µmol TE/g (Güney, 2020). Compared to these studies, the antioxidant capacity of the oil sample was slightly lower.

3.2. Thermal properties of the oil

The melting and crystallization temperatures, enthalpies, and OIT of the oil are presented in Table 3. Greater amounts of saturated fatty acids are known to cause higher melting temperatures (Mayfield *et al.,* 2015). Unsaturated fatty acids were dominant in the oil, so, a lower melting point was an expected result. There is no data in the literature for direct comparison. In the study by Ramos *et al.* (2016), the thermal properties of seeds, pulp, leaves and seed oil of *Rosa rubiginosa* were investigated. In the thermal analysis of the seeds, a peak at around -37 ºC was observed

Table 3. Thermal properties of the oil

Property	Value
Melting	
$Onset_m$ (°C)	-25.56 ± 0.17
T_m (°C)	-22.13 ± 0.15
ΔH_m (J/g)	16.68 ± 1.41
Crystallization	
$Onset_c$ (°C)	-45.25 ± 1.15
T_c (°C)	-47.00 ± 1.42
ΔH_c (J/g)	-29.92 ± 1.76
OIT (170°C, min)	3.85 ± 0.04

Results are expressed as mean ± SE.
Each analysis was done at least in duplicate, or in triplicate.
OIT: Oxidative induction time.

and this peak was associated with the crystallization of α-linolenic acid and linoleic acid, which are major fatty acids in the seed oil. The results of this study are similar to this study.

OIT is the time required for the onset of oil oxidation at a given temperature and it is used as an indicator of the oxidative stability of oils. The OIT of our oil sample was determined as 3.85 min at 170 °C. It is thought that the oxidative stability of the oil was low because it was rich in polyunsaturated fatty acids (Table 4). In one study, rosehip seed oils from two different manufacturers were analyzed at 140 °C and the OIT values were found as 26 min and 23 min (Grajzer *et al.,* 2015). The OIT value for our sample is much lower, probably, due to differences in the analysis temperatures. Clearly, this oil has low oxidative stability near frying temperatures.

3.3. Fatty acid, sterol, and tocopherol compositions of the oil

Thirteen fatty acids were determined in rosehip seed oil and the results are presented in Table 4. It was observed that rosehip seed oil contained higher amounts of unsaturated fatty acids (92.5%). Linoleic acid was determined as the major fatty acid with 51.1% and it was followed by α-linolenic acid and oleic acid with 21.4 and 19.3%, respectively. In one study (İlyasoğlu, 2014), linoleic acid, oleic acid, and α-linolenic acid were measured as major fatty acids with 54.05, 19.50, and 19.37%, respectively. In another study (Grajzer *et al.,* 2015), cold-pressed rosehip seed oils from two different manufacturers were analyzed and linoleic acid, oleic acid, and α-linolenic acid were found as major fatty acids with 51.7-44.4, 16.3-14.7 and 21.5-31.8%, respectively. In general, the results concur with the literature.

The sterol composition of the cold-pressed rosehip seed oil is presented in Table 4. β-Sitosterol was determined as the major sterol with 84.6%. It was followed by Δ-5-avenasterol (3.8%), campesterol (3.7%), Δ-7-stigmastenol (2.7%), and stigmasterol (1.6%). In a study (İlyasoğlu, 2014), β-sitosterol, Δ-5-avenasterol, campesterol and Δ-7-stigmastenol contents were measured as 544, 31.6, 23.3 and 41.4 mg/100g, respectively. In the study of Grajzer *et al.* (2015), the β-sitosterol, Δ-5-avenasterol, campesterol and stigmasterol contents of the cold-pressed rosehip seed oils were found to be 5297.3-4753.3, 242.4-379.1, 192.3-205.4, and 77.9-60.2 mg/kg, respectively. The data seems to be within the ranges reported in the literature.

Table 4. Fatty acid, sterol, and tocopherol compositions of the oil

Compound	Value
Fatty acids (%)	
Palmitic	3.70 ± 0.01
Palmitoleic	0.10 ± 0.05
Margaric	0.10 ± 0.00
Heptadecenoic	0.10 ± 0.00
Stearic	2.20 ± 0.00
Oleic	19.30 ± 0.05
Linoleic	51.10 ± 0.05
α-Linolenic	21.40 ± 0.05
Arachidic	1.10 ± 0.00
Eicosanoic	0.40 ± 0.00
Arachidonic	0.10 ± 0.00
Behenic	0.20 ± 0.05
Lignoceric	0.10 ± 0.00
ΣSFA	7.50
ΣUFA	92.50
Sterols (%)	
β-Sitosterol	84.60 ± 3.60
Δ-5-Avenasterol	3.80 ± 0.01
Campesterol	3.70 ± 0.00
Δ-7-Stigmastenol	2.70 ± 0.02
Stigmasterol	1.60 ± 0.00
Δ-7-Avenasterol	1.00 ± 0.00
Δ-5.24- Stigmastadienol	0.60 ± 0.00
Clerosterol	0.60 ± 0.00
Cholesterol	0.60 ± 0.00
Brassicasterol	0.20 ± 0.00
Erythrodiol+Uvaol	0.20 ± 0.01
Tocopherols (µg/g oil)	
γ-Tocopherol	773.76 ± 161.21
α-Tocopherol	266.08 ± 39.6
δ-Tocopherol	35.83 ± 0.75
β-Tocopherol	6.33 ± 1.49
Total	1082

Results are expressed as mean ± SE.
Each analysis was done at least in duplicate, or in triplicate.
SFA: Saturated fatty acid; UFA: Unsaturated fatty acid.

Tocopherols are known as oil-soluble antioxidant and sources of vitamin E. As seen in Table 4, the total tocopherol content in the oil was measured as 1082 µg/g oil. γ-Tocopherol (773.76 µg/g

oil) was determined as the major tocopherol and it was followed by α-tocopherol (266.08 µg/g oil). In one study (Fromm *et al.,* 2012), the total tocopherol content in the rosehip seed oil was measured as 1099.9 mg/kg oil and γ-tocopherol was determined as the major tocopherol. In another study (Grajzer *et al.,* 2015), the tocopherol compositions of cold-pressed rosehip seed oils from two different manufacturers were analyzed. The total tocopherol contents in the rosehip seed oils were determined as 1124.7 and 1037.6 mg/kg oil and, γ-tocopherol was found as the major tocopherol in both oils. The tocopherol composition of the oil is similar to those reported in the literature.

3.4. Phenolic composition of the oil

The phenolic composition of cold-pressed rosehip seed oil is presented in Table 5. Fifteen types of phenolic compounds were quantified in the oil. Rosmarinic acid was the major phenolic compound with 31.38 µg/g oil. It was followed by benzoic acid, campherol, vanillin, caffeic acid, catechin, and quercetin. In one study (Grajzer *et al.,* 2015), the phenolic compositions of cold-pressed rosehip seed oils from two different manufacturers were analyzed. In one of the samples, *p*-coumaric acid was determined as the major phenolic compound, followed by vanillic acid, ferulic acid, and vanillin. In the other sample, again, *p*-coumaric acid was found to be the major phenolic compound, followed by vanillin, vanillic acid, and sinapinic acid. Our results are quite different from these studies, probably because of the differences in genotype of the seeds and agricultural conditions.

Table 5. Phenolic composition of the oil

Phenolic compound	Value (µg/g oil)
Protocatechic acid	0.08 ± 0.00
Catechin	0.96 ± 0.08
p-Hydroxybenzoic acid	0.46 ± 0.02
Caffeic acid	0.93 ± 0.03
Syringic acid	0.23 ± 0.01
Vanillin	1.10 ± 0.01
p-Coumaric acid	0.13 ± 0.00
Ferulic acid	0.45 ± 0.00
Benzoic acid	2.01 ± 0.12
o-Coumaric acid	0.05 ± 0.01
Hesperidin	0.27 ± 0.08
Rosmarinic acid	31.38 ± 1.09
Cinnamic acid	0.42 ± 0.01
Quercetin	0.82 ± 0.01
Kaempferol	1.30 ± 0.07

Results are expressed as mean ± SE. Analysis was done in duplicate.

3.5. Aromatic volatile compounds in the oil

The aromatic volatile compounds detected in the oil are presented in Table 6. Sixty-seven aromatic volatile compounds were quantified in cold-pressed rosehip seed oil. L-Limonene, which has aroma descriptions such as orange, terpene, and pine, was detected as a major aromatic volatile compound with a ratio of 24%. It was followed by 2,4-heptadienal, (E,E) (7.58%) and hexanal (7.02%), which have aroma descriptions such as fresh, green, vegetable. Linalyl acetate (sweet, green, bergamot, lavender), beta-myrcene (peppery, terpene, spicy), and *trans*-2-nonenal (oily, green, cucumber) were also detected in the oil at a ratio of approximately 4%. Dominant volatile compounds in the oil concur with the descriptive terms determined with the sensory descriptive analysis.

To the best of our knowledge, there is no study in the literature about the aromatic volatile compounds in the cold-pressed rosehip seed oil. In the study of Murathan *et al.* (2016), oil was extracted from rosehip fruit with soxhlet equipment and aromatic volatile compounds were analyzed. Butanoic acid, 1,2-propanediol, α-caryophyllene and naphthalene were determined predominantly. The data on volatile aromatics would greatly contribute to the literature referring to cold-pressed rosehip oil.

3.6. Sensory descriptions of the cold pressed rosehip seed oil

The sensory descriptive terms developed for the cold-pressed rosehip seed oil are shown in Table 7. Five sensory attributes were determined for description of the cold-pressed rosehip seed oil, namely spicy, earthy, timber/kindling, raw vegetable and bitter. Timber/kindling and raw vegetable tastes/aromas were found to be relatively dominant. Generally, these results concur with the results from the aromatic volatile compounds analysis. To the best

TABLE 6. **Aromatic volatile compounds in the oil**

No.	RI[a]	Volatile compound	Aroma definition[b]	Area %
1	445	Ethanol	Strong alcoholic, ethereal, medical	1.15 ± 0.1
2	500	2-Propanone	Solvent, ether, apple	1.58 ± 0.0
3	602	Acetic acid	Sour, burning, cheesy	4.04 ± 0.8
4	623	2-Butenal	Flower	0.95 ± 0.1
5	678	1-Penten-3-one	Pepperoni, onion	0.15 ± 0.0
6	690	Propionic acid	Acid, cheese, vinegar	0.13 ± 0.0
7	698	Pentanal	Fermented bread	0.48 ± 0.1
8	723	3-Methyl-1-butanol	Fusel oil, whiskey, fruity	1.96 ± 0.3
9	750	2-Pentenal, (E)-	Green, tomato, fruit	0.45 ± 0.0
10	773	Toluene	Sweet	0.25 ± 0.0
11	790	1-Octene	Kerosene	0.08 ± 0.0
12	799	Hexanal	Fresh, green, leaf	7.02 ± 0.1
13	851	(E)-2-Hexenal	Green, banana, cheese	1.86 ± 0.1
14	892	Styrene	Sweet balm, flower	0.61 ± 0.0
15	908	o-Xylene	Geranium	0.16 ± 0.0
16	911	2,4-Hexadienal	Oily, sweet, green, spice	0.07 ± 0.0
17	915	2-Acetylfuran	Sweet balm, almond, caramel	0.07 ± 0.0
18	924	α-Thujene	Woody, green grass	2.47 ± 0.5
19	928	Pentanoic acid	Acidic, sharp, cheese	0.22 ± 0.0
20	948	α-Pinene	Fresh camphor, pine, woody	0.46 ± 0.1
21	952	*trans*-2-Heptenal	Green, vegetables, oily	2.27 ± 0.2
22	954	Benzaldehyde	Sharp, almond, bitter	0.52 ± 0.0
23	958	Heptenal	Fruity, green	0.24 ± 0.0
24	972	1-Octen-3-ol	Fungus, soil, mold, green	0.31 ± 0.0
25	973	β-Pinene	Dry wood, pine, green	0.25 ± 0.0
26	978	1-Octen-3-one	Herbaceous, mushroom, soil	0.08 ± 0.0
27	983	β-Myrcene	Peppery, terpene, spicy	4.16 ± 0.7
28	986	6-Methyl-5-hepten-2-one	Citrus, green, apple	0.89 ± 0.0
29	1000	*trans, trans*-2,4-Heptadienal	Oily, green, vegetable	2.26 ± 0.1
30	1003	Hexanoic acid, ethyl ester	Sweet fruit, pineapple, banana	0.84 ± 0.1
31	1007	Octanal	Aldehyde, waxy, orange peel, oily	0.43 ± 0.0
32	1009	δ-3-Carene	Citrus, herbaceous, pine	0.47 ± 0.0
33	1012	l-Phellandrene	Mint, menthol	0.35 ± 0.0
34	1013	2,4-Heptadienal	Oily, green, vegetable	7.59 ± 0.1
35	1023	Cymene	Fresh citrus, terpene, spice	3.18 ± 0.1
36	1027	l-Limonene	Orange, terpene, pine	24.8 ± 0.1
37	1030	Eucalyptol (1,8-cineole)	Eucalyptus, camphor, medicine, herb	1.02 ± 0.1
38	1036	*cis*- Ocimene	Citrus, tropical, green, terpene	0.21 ± 0.0
39	1042	Oct-3(E)-en-2-one	Earthy, spicy, sweet, mushroom	0.16 ± 0.0
40	1044	β-Ocimene	Citrus, tropical, green, woody	0.58 ± 0.0
41	1059	2-Octenal	Oily, sweet, green	0.63 ± 0.2
42	1080	Heptanoic acid	Rancid, sour cheese, sweat	0.07 ± 0.0
43	1081	3,5-Octadiene-2-one	Fruity, oily, mushroom	0.70 ± 0.0
44	1083	α-Terpinolene	Fresh, woody, pine, sweet	0.07 ± 0.0
45	1086	1-Methyl-4-isopropenylbenzene	Phenolic, spicy, clove	0.13 ± 0.0
46	1093	2-Nonanone	Fresh, green, herbaceous	0.14 ± 0.1
47	1095	Ethyl heptanoate	Fruity, pineapple, wine	0.09 ± 0.0
48	1102	Linalool	Citrus, flower, sweet	1.90 ± 0.0
49	1103	Nonanal	Waxy, aldehydeic, citrus, lemon	1.42 ± 0.3
50	1120	*cis*-Methyl-4-octenoate	Green, fruity, waxy	0.29 ± 0.0
51	1125	Methyl octanoate	Waxy, green, orange, vegetable	0.22 ± 0.0
52	1128	Sabinene	Woody, terpene, pine	0.14 ± 0.1
53	1135	Camphor	Mint, herbaceous	0.24 ± 0.0
54	1155	2,6-Nonadienal, (E,Z)-	Green, oily, cucumber	0.51 ± 0.0
55	1161	*trans*-2-Nonenal	Oily, green, cucumber	4.15 ± 0.1
56	1184	4-Octenoic acid, ethyl ether	Fruity, pear, citrus	0.23 ± 0.0
57	1185	Decanal	Sweet, waxy, orange peel, flower	0.16 ± 0.0
58	1200	Dodecane	Alkane	0.67 ± 0.0
59	1202	Benzaldehyde, 2-hydroxy-6-methyl	Almonds, cherries	0.36 ± 0.0
60	1215	2,4-*trans, trans*-Nonadienal	Oily, melon, waxy, green	0.07 ± 0.0
61	1261	Linalyl acetate	Sweet, green, bergamot, lavender	4.42 ± 0.5
62	1263	*trans*-2-Decenal	Waxy, oily, earthy, mushroom	0.12 ± 0.0
63	1265	*trans*-Anethole	Sweet anise, licorice, mimosa	0.53 ± 0.0
64	1331	2,4-Decadienal	Orange, sweet, fresh, citrus,green	1.50 ± 0.2
65	1342	Neryl acetate	Floral, rose, soap	0.14 ± 0.0
66	1457	Alloaromadendren	Woody	0.10 ± 0.0
67	1469	1-Dodecanol	Soil, soap, waxy, coconut	0.18 ± 0.0

Results are expressed as mean of Area %. Analysis was done in duplicate.

[a] RI (Kovat Index) on Rtx-5 MS column

[b] Aroma definitions of the volatile compounds are found from the web pages of http://www.thegoodscentscompany.com and http://www.flavornet.org

TABLE 7. **Sensory descriptive properties of the oil**

Property	Value
Spicy	1.2 ± 0.3
Earthy	1.0 ± 0.5
Timber/Kindling	5.8 ± 0.7
Raw Vegetable	3.5 ± 1.2
Bitter	0.5 ± 0.1

Results are expressed as mean ± SD. Analysis was done in duplicate.

of our knowledge, for comparison, there is no study about the sensory properties of rosehip seed oil in the literature. Therefore, this study provides very important data for those who would have interest in using this oil.

CONCLUSIONS

In this study, rosehip seed oil produced with the cold-press technique was characterized completely. It was observed that cold-pressed rosehip seed oil was rich in unsaturated fatty acids, essential fatty acids, sterols, tocopherols and phenolic compounds. For cold-pressed rosehip seed oil, for the first time, aromatic volatile compounds were determined and sensory descriptive terms were provided. The aroma descriptions of the dominant volatile compounds in the oil were found to agree with the panel and the determined sensory descriptive terms. Acidity and oxidation levels in the oil were found to be slightly high and it was suggested to improve the storage conditions of both the seeds and pressed oils. In conclusion, rosehip seeds can be utilized for edible and nutritionally-rich cold-pressed oil production for various food applications, functional foods and cosmetics.

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