Research Article

Sour Cherry (Cerasus vulgaris Miller) Kernel Oil as the Novel Functional Edible Oil: Sensory Evaluation and Antioxidant and Physicochemical Properties

Maryam Kazempour-Samak,1 Ladan Rashidi,2 Mehrdad Ghavami,1 Anoosheh Sharifan,1 and Fakhrisadat Hosseini3

1Department of Food Science and Technology, Faculty of Agriculture Science and Research Branch, Islamic Azad University, Tehran, Iran
2Food Technology and Agricultural Products Research Center, Standard Research Institute, PO Box 31745-139, Karaj, Iran
3Department of Biology Science, Faculty of Biotechnology, Alzahra University, Tehran, Iran

Correspondence should be addressed to Ladan Rashidi; l.rashidi@standard.ac.ir

Received 1 February 2021; Revised 25 April 2021; Accepted 21 May 2021; Published 31 May 2021

Abstract

This study aims to extract oil from fresh sour cherry kernel (Cerasus vulgaris Miller) using the cold press method. The oil content and moisture were obtained as 31.89% and 4%, respectively. The organoleptic assessment of the oil was acceptable and the free fatty acid value was obtained as 1.36 (mg KOH/g oil). In addition, peroxide value and anisidine index of sour cherry kernel oil were obtained as 0.99 meqO₂/kgoil and 0.15, respectively. The predominant fatty acids were linoleic acid (42.34%), oleic acid (35.45%), α-eleostearic acid (9.34%), and palmitic acid (6.54%), respectively. The kernel oil contained nine major triacylglycerols consisting of OLL (20.44%), OOL (16.99%), LLL (8.20%), LLEl (7.28%), PLO (7.24%), OEO (5.03%), OOOL (4.54%), PLL (4.35%), and POO (3%), respectively. The most abundant sterol compounds were β-sitosterol (83.55%), ∆5-avenasterol (6.8%), sitostanol (4.8%), campesterol (3.5%), and stigmasterol (0.53%), respectively. Also, antioxidant activity, total phenol content (TPC), total anthocyanin content (TAC), total flavonoid content (TFC), total tannin content (TTC), and total tocopherol content were obtained as 73.22%, 33.44 mg GA/g dry matter, 177.84 mg/L, 46.37 mg/g dry matter, and 1.21 mg GA/g dry matter, 832.5 mg/kg oil, respectively. The amount of amygdalin in the oil sample was not detectable.

1. Introduction

Sour cherry (Prunus Cerasus L.) is a popular fruit belonging to the family of Rosaceae, subfamily Prunoideae. Sour cherry is widely used across North America, Europe, and Asia. The global production of sour cherry fruit has increased during the past few years and has reached 14.1 to 38.1 million tons in the years 2006 to 2016 [1]. Nowadays, sour cherry can be used as a kind of fresh fruit as well as juice, dried product, syrup, additive, and jam. This fruit is a rich source of phytochemicals and nutraceuticals, including anthocyanins with bioactive properties such as antioxidation and anti-inflammation, which could inhibit tumor development and prevent colon cancer [1].

A large part (approximately 85%) of the annual production of sour cherries is processed, which includes juice or concentrate and frozen pitless sour cherry that produces a large amount of waste (kernels and pomace). Now, the main part of these wastes is used as animal feed or is discarded, and only a very small amount of these byproducts can be used [1, 2]. Sour cherry pomace is a very valuable and rich source of bioactive compounds, including anthocyanins, polyphenols, flavonols, and red and purple pigments, which can be applicable in food and pharmaceutical products [2]. Encapsulated bioactive compounds of sour cherry pomace have also been applied in the cookies formulation. Results showed that applying encapsulated bioactive components of...
sour cherry pomace improves the functional properties of the cookies and their stability during storage [3]. Sour cherry kernels are the other main byproducts during canning or freezing (also known as pit or stone), which make up about 7–15% of the total fruit weight [1]. In addition, this byproduct of sour cherry processing is a good source of phenolic and antioxidant compounds, fat, protein, and dietary fiber. One of the main components of the sour cherry kernel is oil (17–36%), which is a rich source of polyunsaturated and monounsaturated fatty acids. Amino acids, such as lysine (known as an essential amino acid) and glutamic acid (dominant amino acid), minerals such as calcium and potassium, and B vitamins group (B1, B3, B5, and B6) are other valuable compounds found in sour cherry kernel [1]. This kernel contains high content of oil, which can be taken into account as a rich source of bioactive and valuable compounds. Yilmaz et al. (2013) reported the use of carbon dioxide (SC-CO2) to extract oil from sour cherry kernels [1]. Also, the bioactive compounds existing in the extracted oil from sour cherry kernel oil by the various solvents were detected and quantified [4]. It was reported that different methods such as solvent extraction, microwave, ultrasound, and supercritical fluid assisted extraction, enzymatic methods, and cold pressing can be used to extract oil from oilseeds [5]. Kernel oil from Prunus species, including sweet cherry (P. avium L.), sour cherry (P. cerasus L.), apricot (P. armeniaca L.), nectarine (P. persica var. nectarina (Aiton) Maxim.), peach (P. persica (L) Batsch var. persica), and plum (P. domestica L.) contains high levels of unsaturated fatty acids and bioactive compounds [6].

Cold press extraction of oil is one of the methods of mechanical extraction, which requires less energy than other oil extraction methods and is environmental friendly. High quality oils with unique properties can be extracted by this method at low temperature without using the solvent [7]. However, few studies were conducted on physicochemical and antioxidant properties, and quantification and detection of bioactive compounds of extracted oil from sour cherry kernel oil using cold press method. For example, amygdaline is a cyanogenic glycoside which is found in the seeds or kernels of some fruits, including sour cherry kernel (3.89 mg/g kernel). The lethal dose of amygdalin is 0.5–3.5 mg/g body weight (bw) [8]. Amygdalin can be decreased by different procedures, including soaking, drying, crushing, and fermentation. The very low amount of amygdalin is reported in the sour cherry kernel oil using cold press method [8].

This study aims to extract oil from Iranian sour cherry kernel (Cerasus vulgaris Miller) using cold press method. Then, the physicochemical properties of the sour cherry kernel, including oil, moisture, protein, ash, and carbohydrate contents, were determined. In addition, the sensory evaluation and physicochemical and antioxidant properties of the extracted sour cherry kernel oil, including peroxide value, acidity value, anisidine index, oxidative stability, fatty acid, sterol and triacylglycerol compositions, antioxidant activity percentage (AA), total phenol content (TPC), total flavonoid content (TFC), total anthocyanin content (TAC), total tannin content (TTC), and tocopherol content were investigated comprehensively.

2. Materials and Methods

2.1. Materials. Methanol, hexane, potassium hydroxide, hydrochloric acid (HCl), potassium chloride (KCl), Folin-Ciocalteu reagent, DPPH (2,2-diphenyl-1-picrylhydrazyl), quercetin, gallic acid (GA), α-Cholesterol, and sodium carbonate (Na2CO3) were obtained from Merck Chemical Company, Darmstadt, Germany. The reference standard of FAMEs mixture (C4-C24), amygdalin standard, triglycerides mixture standard, and the reference sterol compounds were purchased from Sigma–Aldrich Company, USA.

2.2. Sampling and Preparing Sour Cherry Kernel. Sour cherries were collected in May 2019 from the sour cherry trees cultivated in an orchard located in Lavasan (Lavasan is a prosperous town in Shemiranat County, Tehran Province, Iran). The fresh cherry fruits were pitted. The kernels were washed using water, dried in the ambient temperature, between 25°C and 30°C, and stored in the refrigerator at 4°C in sealed bags. The dried kernels were ground and finally sized. The fraction of particle sizes was between 1 and 3 mm. The powder of the kernels was kept in the dark plastic tube at −20°C until analysis.

2.2.1. Physicochemical Characterization of Sour Cherry Kernel. The oil, moisture, protein, total carbohydrate, ash and crude fiber contents of sour cherry kernel were determined according to the test methods described in the ISO 659, ISO 665, ISO 20483, ISO 11292, ISO 2171, and ISO 5498, respectively [9, 10, 11, 12, 13, 14].

2.3. Extraction of Oil from Sour Cherry Kernel Using Cold Press Method. The sour cherry kernel oil was mechanically extracted using the laboratory cold press machine (cold press hydraulic oil press machine, model 6YY-270, power 2.2 (kW), Anyang Best Complete Machinery Engineering Co., Ltd, China). The temperature of the oil extraction process was not more than 35°C–40°C. The oil was centrifuged and then filtered to remove foreign materials. The temperature of extracted oil after filtration was around 32°C. The oil was kept in a dark bottle at −20°C until analysis.

2.3.1. Physicochemical Properties and Sensory Analysis of Sour Cherry Kernel Oil. Sensory analysis was performed by the six trained panelists (age between 25 and 32 years old) from Standard Research Institute of Iran in terms of taste, color, and odor according to the ASTM E1627-19 method [15]. Moisture content, peroxide and acidity values, and anisidine index of the sour cherry kernel oil were determined according to the described test methods in the ISO 8534, ISO 3960, ISO 660, and ISO 6885, respectively [16–19]. Saponification value, unsaponifiable matter, iodine value, and oxidative stability of sour cherry kernel oil were determined
according to the methods explained in the ISO 3657, ISO 18609, ISO 3961, and ISO 6886, respectively [20, 21, 22, 23].

2.3.2. Fatty Acid, Triacylglycerols (TAGs), and Sterol Analyses of the Oil. Fatty acid methyl esters (FAMEs) of sour cherry kernel oil were prepared according to the described method in the ISO 12966–4: 2015 and then were injected into the gas chromatography (GC) (Yung Lin 6100, Korea) equipped with a flame ionization detector (FID) [24]. Fatty acids composition of sour cherry kernel oil was measured by GC equipped with a CP-SIL88 capillary column (100 m × 0.25 mm i.d. with 0.2 μm film thickness) (Varian Inc.). The temperatures of the injector and detector were adjusted to 260 °C and 280 °C, respectively, for 120 min at 78.5°C. The extract was filtered and ethanol added and the mixture was boiled using a rotary evaporator round-bottom flask (100 mL); then, 50 mL of ethanol was added and mixed. The mixture was incubated for 3 min at room temperature followed by sonication for 5 min [25].

TAGs composition of sour cherry kernel oil was gained by high-performance reverse phase chromatography (HPLC) (Young Lin 9100, South Korea) equipped with the refractive index detector (RI) and the LiChrosorb® RP-18 column of 250 mm length, 4 mm diameter, and 5 μm particle size. The mobile phase was acetonitrile and acetone (50:50, v/v) at the flow rate of 1 mL/min and the column temperature of 45°C [25].

The individual and total sterol content of sour cherry kernel oil were determined based on the procedure explained in ISO 12228:2014 [26].

2.3.3. Amygdalin Content. The amygdalin content in sour cherry kernel oil was measured using the method developed by Pavlović et al. [8]. Briefly, 2 g of oil was weighted in the round-bottom flask (100 mL); then, 50 mL of ethanol was added and the mixture was boiled using a rotary evaporator for 120 min at 78.5°C. The extract was filtered and ethanol completely evaporated in the vacuum oven at 30°C. The final extract was put in a desiccator. Then, diethyl ether (10 mL) was added and mixed for 1 min at the ambient temperature to precipitate amygdalin. Diethyl ether was evaporated using the nitrogen gas. The dried residue was dissolved in the deionized water (5 mL), filtered using 0.2 μm PTFE filter, and injected to the HPLC. The HPLC was equipped with the UV detector and the RP-18 column (250 mm × 4.6 mm; 5 μm). The water: acetonitrile (25:75) as the mobile phase was applied. The flow rate was 1 mL/min and the wavelength of detection was 210 nm.

2.3.4. Extracting Phenolic Compounds. Polyphenol compounds were extracted using a mixture of ethanol: water (80:20) followed by sonication for 5 min [25].

(1) Determining of Bioactive Compounds

(1) Total Phenol Content (TPC). By colorimetric assay, TPC in the ethanolic extract of sour cherry kernel was measured [25]. In addition, 200 μL of sour cherry kernel oil extract, 800 μL of deionized water, and 100 μL of Folin-Ciocalteu reagent were mixed. The mixture was incubated for 3 min at room temperature. Then, 300 μL of sodium carbonate (Na2CO3) (20% (w/v)) was added to the mixture and incubated again for 2 h in a dark place at 25°C. The absorbance of the solution was obtained using UV/Vis Spectrometer (Lambda 25–Perkin Elmer, USA) at 765 nm. In the range of 0–100 μg/mL, the calibration curve of gallic acid (GA) standard was obtained. TPC was represented as mg GA equivalent per g dry matter [1, 25]. All the tests were done in triplicate.

(2) Total Tannin Content (TTC). The quantity of TTC of sour cherry kernel oil extract was determined using UV/Vis spectrometer (Lambda 25-Perkin Elmer, USA) at 725 nm. TTC was expressed as GAE/g dry matter. Firstly, 100 μL kernel oil extract was added to 750 μL distilled water. Then, 500 μL Folin-Ciocalteu reagent and 1000 μL of sodium (35% (w/v)) were mixed. At room temperature, the mixture was shaken and diluted to 10 mL with distilled water and incubated for 30 min. As mentioned, the calibration curve of the GA standard solution was prepared in the range 0–100 μg. All the tests were conducted in triplicate [25].

(3) Total Flavonoid Content (TFC). TFC of the sour cherry kernel was determined with the colorimetric assay and expressed as mg quercetin equivalent (QE)/g dry matter [25]. Briefly, at room temperature, 150 μL of sodium nitrite (NaNO2) (5% (w/v)) was added to 200 μL of kernel oil extract and incubated for 6 min. Then, 150 μL of AlCl3·6H2O (10% (w/v)) was added and again incubated for 6 min. Thus, 800 μL of NaOH solution (10% (w/v)) was added to the mixture solution and incubated at room temperature for 15 min. The control sample (blank), instead of kernel oil extract, was distilled water. The absorbance was recorded at 510 nm. All the tests were performed in triplicate. The calibration curve of quercetin (QE) standard was achieved in the range of 0–100 μg/mL (using 80% ethanol) [25].

(4) Antioxidant Activity Percentage (AA%). The antioxidant activity percentage of the sour cherry kernel oil extract was determined according to the described method by Khadem et al. [25]. 1 mL of DPPH solution (0.1 mM) was added to 3 mL of sour cherry kernel oil extract and, then, put it in a dark place for 30 min at room temperature. The absorbance of the sample was determined at 517 nm by UV/Vis spectrophotometer. Comparison of DPPH radical scavenging activity to the control was obtained using

\[
\text{DPPH scavenging activity} = \frac{A_0 - A_1}{A_0} \times 100, \quad (1)
\]

where \( A_0 \) and \( A_1 \) are control absorbance and sample absorbance, respectively [25].

(5) Total Anthocyanin Content (TAC). TAC of the sour cherry kernel oil extract was measured based on different pHs, including pHs 1 (0.025 M potassium
chocolate) and 4.5 (0.4 M sodium acetate buffer) [25]. For this purpose, 0.1 mL of the extract was diluted to 10 mL using the buffer solution. The sample absorption was determined at both wavelengths 510 and 700 nm. The TAC (expressed as mg cyaniding 3-glucoside/mL) of the samples was obtained using:

\[
\text{TAC} = \frac{(A \times \text{MW} \times \text{DF} \times 1000)}{(\text{EXT})}
\]

where \( \text{MW} \) is the molecular weight (cyanidin-3-glucoside, \( \text{MW} = 449.2 \)), \( \text{DF} \) is the dilution factor, and \( \varepsilon \) is the molar absorptivity; pigment content was calculated by:

\[
A = (A_{510} - A_{700}) \times \text{pH}_1 - (A_{510} - A_{700}) \times \text{pH}_{4.5}
\]

3.2. Physicochemical Properties of Sour Cherry Kernel Oil

3.2.1. Peroxide Value (PV), Acidity Value (AV), Anisidine Index (AI), Oxidative Stability (OS), Sensory Evaluation, and Amygdaline Detection. It is generally found that the chemical properties of oils and fats directly affect their physical properties. The presence of specific functional groups in the structure of lipids not only affects their physical and chemical properties, but also influences the functional properties of fats as well as the purpose of their applications in food [29].

Table 1 shows the results of AV, PV, AI, and OS of sour cherry kernel oil. The peroxide value of this oil was obtained as 0.99 mEq O₂/kg oil, which was lower than that of the specified limitation for cold pressed or virgin oils [31]. It was reported that the peroxide value of sour cherry kernel oil from Banat, Romania, was 1.2 mEq O₂/kg oil [29].

AV of this sour cherry kernel oil was obtained as 1.36 mg KOH/g oil, which was higher than that of the reported in another research for sour cherry kernel oil acid value, 1 mg KOH/g oil [29]. In another study, PV of sour cherry kernel oil was obtained as 1.45 mg KOH/g oil [32]. The OS of sour cherry kernel oil was determined by the accelerated oxidation technique using the Rancimat instrument. The OS of Iranian sour cherry kernel oil was obtained 3.0 h at 110°C, which was higher than the Turkish sour cherry kernel oil (1.3 h) [33]. The OS of Montmorency sour cherry (Prunus cerasus L.) pit oil was analyzed using differential scanning calorimetry (DSC) at 130°C and the OS was obtained as 30.30 min [32].

AI shows the secondary oxidation of oil and fat and determines the amount of aldehydes and ketones, which are the indicators of oxidation development and excessive oil deterioration. Based on the result, AI of sour cherry kernel oil was obtained 0.15, which indicates the quality of oil is suitable. Iodine value exhibits stability against oxidation and a degree of unsaturation for applying oil in the industry. In addition, the saponification value was applied for evaluating...
The sensory evaluation of the cold-pressed sour cherry kernel oil was carried out with six trained tasters [15]. All the tasters of the panel were trained in different characteristic attributes of cold-pressed sour cherry kernel oil flavors. They were familiar with the main defects of these oils such as aging and sediment, mold and moisture (smell), burnt and roasted (smell and taste), acidic (taste), sour (smell and taste), bitter (taste), oxidative decay or sharpness (smell), metal (taste), grain kernel similar to grain or fruit (smell), pure (smell and taste), and freshness (taste). The oil samples (15 mL) were served in the special vessels at room temperature. The flavor and taste of the oils were characterized according to the sensory description form. Indicators of negative sensory evaluations, including burn taste and smell, acidity, bitter taste, pungent smell, and metallic taste of the sample and positive sensory evaluation indicators of grain kernel (similar to grain or fruit) as purity and freshness were checked [15]. Results showed that the appearance of the sour cherry kernel oil sample was observed without impurities at 20°C for 24 h. The oil of sour cherry kernel was clear. The smell of the cold-pressed oil of sour cherry kernel was similar to that of bitter almonds. The color of sour cherry kernel oil was yellow and its flavor was slightly sweet. No defects were observed in the sour cherry kernel oil.

3.2.2. Fatty Acids Composition. The results of fatty acids composition of sour cherry kernel oil are shown in Table 2. The UFA content (88.80%) was higher than that of SFA level (11.2%) andPUFA level (52.66%) was more than that of MUFA level (36.14%). The predominant fatty acids in sour cherry kernel oil were linoleic acid (42.34%), oleic acid (35.45%), α-eleostearic acid (9.34%), and palmitic acid (6.54%), respectively, which constituted 93.67% of the total fatty acid composition. A higher ratio of ΣUFAs to SFAs makes oil more susceptible to oxidation. According to the results, the ratio of ΣUFA/ΣSFA was obtained 7.928, which showed this oil was more susceptible to oxidation. However, nutritionists always recommend the consumption reduction of saturated fatty acids and the consumption increase of omega-3 and omega-6 fatty acids. Various factors such as climatic conditions, geographical area, species, harvest year, cultivar, and ripening stage are effective factors in fatty acid composition [36]. The fatty acids composition of this sour cherry kernel oil was similar to that reported in the other research. The composition of fatty acids extracted from the kernels of six sour cherry cultivars showed that the most abundant fatty acids detected were linoleic acid (35.50–46.06%), oleic acid (25.25–45.30), α-eleostearic acid (7.43–15.76%), and palmitic acid (5.06–7.38%) [4]. The amounts of SFAs in these varieties ranged from 9.40% to 11.7% and their MUFA levels ranged from 26 to 46.10% and 44 to 62.30%, respectively [4]. Oleic acid and linoleic acid of sweet cherry seed oil were in the range of 42.625% to 55.265% and 23.276%, respectively [37]. The presence of α-eleostearic fatty acid in the oil extracted from the sour cherry kernel of Turkey has not been reported [1]. However, the presence of α-eleostearic acid (7.43–15.76%) in oils extracted from six sour cherry cultivars of the Baltic countries and Russia has been reported [4].

3.2.3. Triacylglycerols (TAGs) Composition. The amount of each triglyceride corresponding to TAGs was obtained by HPLC equipped with refractive index [25] (Table 3). It was found that the most abundant TAGs found in sour cherry kernel oil were oleodilinolein (OLL) (20.44%), dioleolinolein (OOL) (16.99%), trilinolein (LLL) (8.20%),

| Acid value (mg KOH/g oil) | PV (mEq O2/ kg oil) | Amygdalin content (mg/g) | Anisidine index | OS (h) | Iodine value (mg I2/g fat) | Saponification value (mg KOH/g fat) | Unsaponifiable matter (%) |
|--------------------------|---------------------|--------------------------|-----------------|--------|--------------------------|------------------------------------|--------------------------|
| 1.36 ± 0.13              | 0.99 ± 0.08         | ND                       | 0.15 ± 0.02     | 3.00 ± 0.20 | 130.99 ± 0.22          | 194.0 ± 0.10                    | 0.89 ± 0.01               |
Table 2: Fatty acid composition of sour cherry kernel oil.

| Fatty acid          | Short name | Value (%) |
|---------------------|------------|-----------|
| Caprylic acid       | C8:0       | 0.06 ± 0.02 |
| Capric acid         | C10:0      | 0.07 ± 0.01 |
| Lauric acid         | C12:0      | 0.11 ± 0.03 |
| Myristic acid       | C14:0      | 0.08 ± 0.01 |
| Myristoleic acid    | C14:1 c    | 0.03 ± 0.02 |
| Palmitic acid       | C16:0      | 6.54 ± 0.12 |
| Palmitoleic acid    | C16:1 c    | 0.50 ± 0.23 |
| Heptadecanoic acid  | C17:0      | 0.13 ± 0.01 |
| Cis-Heptadecenoic acid | C17:1 c | 0.10 ± 0.02 |
| Stearic acid        | C18:0      | 2.03 ± 0.04 |
| Oleic acid          | C18:1 c    | 35.45 ± 0.24 |
| Linoleic acid       | C18:2 c    | 0.39 ± 0.01 |
| Linoleic acid       | C18:2 c    | 42.34 ± 0.26 |
| Arachidic acid      | C20:0      | 0.87 ± 0.01 |
| Linolenic acid      | C18:3 c    | 0.13 ± 0.02 |
| γ-linolenic acid    | C18:3 cγ   | 0.46 ± 0.03 |
| α-Eleostearic acid  | C18:3 cδ   | 9.34 ± 0.46 |
| Eicosenoic acid     | C20:1 c    | 0.03 ± 0.01 |
| Behenic acid        | C22:0      | 0.18 ± 0.01 |
| Erucic acid         | C22:1 c    | 0.03 ± 0.01 |
| Lignoceric acid     | C24:0      | 0.14 ± 0.01 |

Data are expressed as the means ± SD for three replicates, p ≤ 0.001.

Table 3: TAGs composition of sour cherry kernel oil.

| TAGs    | Value (%) | TAGs    | Value (%) |
|---------|-----------|---------|-----------|
| LLL     | 8.200     | SLL     | 1.219     |
| EIEIE   | 0.089     | EIEI    | 1.619     |
| EIEIO   | 1.345     | EIEIPE  | 0.423     |
| LLEI    | 7.287     | EIEPO   | 0.804     |
| OEIO    | 5.033     | EILP    | 0.968     |
| EIO     | 4.542     | EISO    | 0.225     |
| PoLL    | 0.320     | PLO     | 7.242     |
| OLnP    | 0.574     | PLP     | 0.559     |
| PoOLn   | 0.008     | PoPP    | 0.008     |
| PLnL    | 0.122     | PoOP    | 0.094     |
| PnPn    | 0.002     | LnPP    | 0.008     |
| PoPoL   | 0.004     | SPOl    | 0.032     |
| PoPoPo  | 0.000     | Sol     | 0.028     |
| SLnLn   | 0.000     | OOO     | 4.707     |
| OLLL    | 20.444    | POO     | 3.009     |
| PoOL    | 0.532     | POP     | 0.464     |
| OOLn    | 0.238     | SLL     | 1.219     |
| PLl     | 4.357     | PPoO    | 0.094     |
| POLn    | 0.150     | PLs     | 0.636     |
| PoPoO   | 0.017     | EILS    | 0.271     |
| PoPOO   | 0.003     | SOL     | 1.991     |
| PoPoL   | 0.113     | SOO     | 0.015     |
| OOL     | 16.990    | POS     | 0.278     |
| PoO0    | 0.147     | SLS     | 0.156     |

L: linoleic acid; O: oleic acid; P: palmitic acid; Po: palmitoleic acid; El: α-eleostearic acid; S: stearic acid; Ln: linolenic acid
dilinoleoleostearin (LLEl) (7.28%), palmitolinoleolein (PLO) (7.24%), dioleoleoleostearin (OOLEl) (5.03%), triolein (OOO) (4.70%), oleosteinoleolein (EILO) (4.54%), palmitoyldilinolein (PLL) (4.35%), and palmitoyldoilolein (POO) (3%). There is no data on the identification of TAGs in sour cherry kernel oil. On sour cherry pit (Prunus cerasus L.) native to the USA (Payson, Utah, USA), it was found that the predominant TAGs were obtained in sour cherry pit oil, including OOO (16.83%), OLO (16.64%), LLO (13.20%), OLP (7.25%), OOP (6.49%), and LEIL (6.16%) [32]. There was little difference between these TAGs composition from the results obtained for sour cherry kernel oil TAGs in this study. It was reported that differences observed in each amount of triacylglycerol are probably due to the variations of geographical conditions, extraction method, and harvest time [32].

3.2.4. Composition of Sterols. Table 4 shows the sterols composition of sour cherry kernel oil. β-sitosterol (83.55%) had the highest quantity among other constituent sterols. Other quantitatively major sterol compounds were Δ5-avenasterol (6.8%), sitostanol (4.8%), campesterol (3.5%), and stigmasterol (0.53%), respectively. It was reported that the dominant sterol compounds in this oil were β-sitosterol (36.10 mg/kg), campesterol (1.59 mg/kg), and stigmasterol (7.2 mg/kg) [32]. Atik et al. reported the sterol compounds of cold press sweet cherry kernel oil (Prunus avium). They found that the most abundant sterols in the sweet cherry kernel oil were β-sitosterol (88.93%), campesterol (3.12%), Δ7-stigmasterol (2.48%), Δ5-avenasterol (2.12%), and sitosterol (1.42%), respectively [38]. These differences may depend on the species differences, geographical area, and extraction methods [32].

3.2.5. TPC, TTC, TAC, TFC, Tocopherol Content, and Antioxidant Activity Percentage (AA%). The results of TPC, TTC, TAC, AA%, TAC, and tocopherols contents of sour cherry kernel oil extract are shown in Table 5. The used calibration curves equations for calculation of TPC, TTC, and TFC were obtained Y = 0.0224X, R2 = 0.9992, Y = 0.0224X, R2 = 0.9992, and Y = 0.0089X + 0.0766 and R2 = 0.9997, respectively. The TPC and AA% of sour cherry oil extract were obtained as 33.44 mg GA/g dry matter and 73.22%, respectively (Table 5). Phenols are bioactive compounds capable of scavenging free radicals and antioxidant activity. These compounds are abundantly found in the plants and, as secondary metabolites, play an important role against oxidative stress. The presence of these compounds in the plant extracts is associated with their antioxidant activity. Therefore, the antioxidant activity of sour cherry kernel extract is related to its phenolic compounds [25]. The results also showed that the TTC, TFC, and TAC of the sour cherry kernel extract were obtained as 1.21 mg GA/g dry matter, 46.37 mg quercetin/g dry matter, and 177.84 mg cyanidin 3-glucoside equivalents/mL, respectively.

Based on the results, α-tocopherol (325 mg/kg oil), γ-tocopherol (470 mg/kg oil), and δ-tocopherol (37.5 mg/kg oil) were the tocopherol compounds found in the extract of sour cherry kernel
Table 4: Sterol composition of sour cherry kernel oil.

| Sterol                | Value (%) |
|-----------------------|-----------|
| Cholesterol           | 0.08 ± 0.01 |
| Brassicasterol        | 0.02 ± 0.02 |
| 24-methylene-cholesterol | 0.02 ± 0.00 |
| Campesterol           | 3.50 ± 0.11 |
| Campestanol           | 0.20 ± 0.03 |
| Stigmasterol          | 0.53 ± 0.00 |
| Delta (7) Campesterol | 0.10 ± 0.01 |
| Clerosterol           | 0.40 ± 0.06 |
| Beta-Sitosterol       | 83.55 ± 5.28 |
| Sitostanol            | 4.80 ± 0.26 |
| Delta (5) Avenasterol | 6.80 ± 0.18 |
| Delta (5), (24) stigmastadienol | 1.40 ± 0.10 |
| D7-Stigmasterol       | 2.30 ± 0.04 |
| D7-Avenasterol        | 2.07 ± 0.03 |

Data are expressed as the means ± SD for three replicates.

Table 5: TPA, TTA, TAC, TFC, AA%, and tocopherol contents of sour cherry kernel oil.

| Property                          | Content                                    |
|-----------------------------------|--------------------------------------------|
| Total phenol content (TPC)        | 33.44 ± 2.35 (mg GA/g dry matter)          |
| Total tannin content (TTT)        | 1.21 ± 0.46 (mg GA/g dry matter)           |
| Total flavonoid content (TFC)     | 46.37 ± 3.87 (mg quercetin/g dry matter)   |
| Antioxidant activity              | 73.22 ± 4.21 (%)                           |
| Total anthocyanin content (TAC)   | 177.84 ± 8.58 (mg cyanidin 3-glucoside/mL) |
| α-tocopherol                      | 325.00 ± 3.29 (mg/kg oil)                  |
| δ-tocopherol                      | 37.50 ± 2.22 (mg/kg oil)                   |
| γ-tocopherol                      | 470.00 ± 5.22 (mg/kg oil)                  |
| Total tocopherol                  | 832.5 ± 10.83 (mg/kg oil)                  |

Data are expressed as the means ± SD for three replicates.

4. Conclusion

Oil scientists are continually looking for new sources of edible oils to introduce new potentials with unique properties. Sour cherry kernel is one of the byproducts of its fruit processing that can be used as a source of edible oil with unique bioactive properties. The oil extracted from sour cherry kernel contains a worthy source of lipophilic bioactive compounds including fatty acids, tocopherols, sterols, anthocyanins, and carotenoids. The Iranian sour cherry kernel oil contains further levels of total tocopherol (832.5 mg/kg oil) and γ-tocopherol (470 mg/kg). The amygdalin content of sour cherry kernel oil was not detectable. In addition, α-eleostearic acid with antitumor activity [4] had a considerable amount (9.34%) in this oil. In this study, most data are presented for the first time for Iranian sour cherry kernel oil. Results of tests showed safety and quality of this oil, but with low oxidative stability of it leading to not having direct consumption of this oil by consumers. Results showed that sour cherry kernel oil contains valuable bioactive compounds, which can be used in food and cosmetic and pharmaceutical formulation industries.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

There are no conflicts of interest.

Authors’ Contributions

The corresponding author is responsible for ensuring that the descriptions are accurate and agreed by all authors. Dr. L. Rashidi conceived the idea, corrected the manuscript, and supervised the work. M. Kazempour carried out the experiments and wrote the manuscript. Dr. Mehrdad Ghavamia, Dr. Anoosheh Sharifana, and Dr. Fakhrisadat Hosseinic supervised the work and edited the manuscript.

Acknowledgments

The authors thank the Iranian National Organization for providing the materials and equipment.

References

[1] C. Yılmaz and V. Gökmen, “Compositional characteristics of sour cherry kernel and its oil as influenced by different extraction and roasting conditions,” Industrial Crops and Products, vol. 49, pp. 130–135, 2013.
[2] J. Bajerska, S. Mildner-Szkudlarz, P. Górnaś, and D. Seglina, “The effects of muffins enriched with sour cherry pomace on extracted oils from 15 apricot kernels (Prunus armeniaca L.) as well as oil yield were affected by the genotype [39].
the plant extract of plum kernel,” *Chemistry Environment*, vol. 16, no. 4, pp. 80–86, 2012.

[36] E. Sipeniece, I. Mišina, A. Grygier et al., “Impact of the harvest year of three cultivars of Japanese quince (Chaenomeles japonica) on the oil content and its composition,” *Scientia Horticulturae*, vol. 275, pp. 109683–2021.

[37] M. Doğantürk and H. S. Canbay, “Oil ratio and fatty acid composition of cherry seed oil,” *Turkish Journal of Health Science and Life*, vol. 2, no. 1, pp. 21–24, 2019.

[38] I. Atik, R. Sevik, and S. Karasu, “Characterization of some physicochemical properties of cold press sweet cherry (*Prunus avium*) seed oil,” *European Journal of Science and Technology*, vol. 17, pp. 959–965, 2019.

[39] P. Górnaś, E. Radziejewska-Kubzdela, I. Mišina, R. Biegańska-Marecik, A. Grygier, and M. Rudzińska, “Tocopherols, tocotrienols and carotenoids in kernel oils recovered from 15 apricot (*Prunus armeniaca* L.) genotypes,” *Journal of American Oil Chemists Society*, vol. 94, pp. 693–699, 2017.