Date Palm Seed Oil (Phoenix dactylifera L.) Green Extraction: Physicochemical Properties, Antioxidant Activities, and Phenolic and Fatty Acid Profiles

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Date palm seed oil is among the precious vegetable oils with low yield, whose extraction is commonly done with organic solvents which cause serious problems. This study aims to assess the effectiveness of orange peel essential oil as biosolvent for date seed oil extraction. Green extraction was conducted by Soxhlet apparatus as well as by soaking and compared with the Soxhlet method using petroleum ether. The GC-MS analysis of orange peel essential oil confirmed its richness with limonene (94.31%), which justifies its usefulness as green solvent. The latter gave higher yields, the extracted bio-oil was light brown with pleasant odor, and the characteristics were consistent with international standards. Based on the GC profiles, obtained oils were similar using both solvents, and the major compounds were oleic and lauric acids. The bio-oil phenolic content and the antioxidant activity were high, and the major compounds were the protocatechuic, chlorogenic, and 4-O-caffeoylquinic acids. Gallic and p-coumaric acids were the major compounds for oil extracted by petroleum ether.

1. Introduction

In recent years, the use of date palm seeds oil (DPSO) has grown around the world especially in cosmetics manufacturing and pharmaceutical industries [1]. This oil is classified among the precious vegetable oils owing to its richness in fatty acids and phenolic and antioxidant compounds. Furthermore, DPSO has multiple benefits on human health [2]. In fact, Besbes et al. [3] have noted that, compared with olive oil, DPSO has higher oxidative stability. In addition, these authors have reported a good capacity of DPSO in the protection against UV light and therefore against cellular damage. Other studies revealed that date seed oils are good sources of α-tocotrienol [4], which is reported as an effective compound to reduce the breast cancer risk [5, 6], cholesterol, and low-density lipoprotein cholesterol in humans [7].
human health [11]. Despite its purification, there may be traces of the solvent that can affect the organoleptic quality of the oil. In addition, organic solvents are volatile compounds, and with high concentrations, ozone and photochemical oxidants are produced [12]. Moreover, solvents may be inhaled into the body, swallowed, or infiltrated through the skin. According to Costa and Aschner [13], most organic solvents may not only cause depression in the central nervous system, but also cause encephalopathy with intellect and memory deterioration.

Recently, the green chemistry focused on safer solvent named “biosolvent” such as terpenes [14]. These latter have interesting chemical properties and exist in many plants especially in citrus fruits. In many industrial applications, terpenes are considered as new alternative to petroleum solvents. Recent attempts have been undertaken to use limonene to extract oil from vegetal materials, whose oil yield and quality are almost like those obtained using hexane [15, 16].

This work was the first on the DPSO green extraction by using the essential oil of orange peel as a green solvent. The aim was to improve the DPSO quality by eliminating the risks resulting from organic solvent.

2. Material and Methods

2.1. Vegetal Material Preparation. The studied date palms in the present study were Phoenix dactylifera L. cv. Deglet Nour from Neftaoua oases, which is a major part of the Tunisian continental oases located in the South West of Tunisia. Trees were irrigated at the rate of 17,000 m³/ha/year and winter fertilization was applied by an average amount per date palm tree of 20 kg for manure. The fresh date fruits were harvested from four date palm trees at full ripening stage and during the season of 2020. The isolated seeds were washed, dried, and then ground to powder form in a grinder. Correspondingly, oranges from the Maltaise demi-sanguine variety (Citrus sinensis) were picked from mature trees. They had spheroid shape, were concave at the base, and had a rounded apex shape and pecked surface texture. The mature orange trees were planted in an orchard located at the Cap-Bon region (North-East of Tunisia), spaced 7 m × 6 m, and were irrigated with drip line with four drippers per tree (41/h). The soil is lithic Leptosols and the average annual precipitation and reference evapotranspiration (ETo-PM) were about 651.3 and 1.080 mm/year, respectively.

2.2. Green Solvent Extraction and GC-MS Analysis. The essential oil extraction from the prepared orange peel was carried out by steam distillation. The steam damages the plant cell structure and releases the volatile molecules which were then dragged towards the refrigerant. Fifty kilograms of fresh orange peel was distilled in a distillation unit operating on a steam-cum-water distillation principle for 3 hours. After the collection of the aqueous phase, the essential oil would subsequently be recovered and then placed in a dark flask.

The gas chromatography-mass spectrometry (GC-MS) analysis of the extracts was performed using a GC-MS (Model, QP 2010, Shimadzu) equipped with an RTX-5MS capillary column of 30 m in length, 0.25 mm in diameter, and 0.25 mm film in thickness. The detection was done by an electron ionization system (70 eV). Helium gas (99.999%), the carrier gas, was used at a constant flow rate of 1.20 ml/min. Injector and mass transfer line temperature were set at 250 and 200°C, respectively. The oven temperature program was from 50 to 250°C at 7°C/min, held isothermally for 2 min, and raised to 250°C at 5°C/min. Samples manual injection in the split mode was done with 50.0 split ratio and with 50–600 AMU mass scan. The total GC-MS running time is 35.50 min. The relative intensity of each volatile compound has been calculated as the ratio between the area of the specific molecule and the sum of the areas of all identified peaks (peak area normalization method) in the chromatogram [17].

2.3. DPSO Extraction by Soxhlet. The DPSO was extracted by using pure solvent at their boiling point and azoetope solvent at their critical solution temperature using Soxhlet apparatus for six hours. Hence, two solvents were used: petroleum ether as pure solvent for classical extraction method and “essential oil + water” (60% + 40%) as azoetope solvent for the green extraction. Solvents were firstly removed by a rotary evaporator and then placed at 40°C overnight to remove the excess of the solvent.

2.4. DPSO Extraction Method by Soaking in Essential Oil. All the steps are shown in Figure 1. Date seed powder was placed in a dark flask and homogenized with essential oil. After mixing for six hours at 45°C, the mixture was centrifuged. The liquid phase was used to recover the essential oil and the DPSO was yielded.

2.5. Physicochemical Characterization. Yields were expressed in % of oil in the basis material. Color and odor were described and the acidity and peroxide values were carried out by standard IUPAC methods [18]. Density meter was used for oil density assessment.

2.6. Fatty Acid Analysis. Fatty acid compositions were determined by GC analysis as described by Nehdi et al. [19]. The fatty acid methyl esters composition was determined by converting the oil to fatty acid methyl esters by addition of 1 ml of n-hexane to 40 mg of oil followed by 200 μl of sodium methoxide (2M). The mixture is heated in the bath at 50°C for few seconds followed by adding 200 μl HCl (2N). The analysis was done using a GC (Agilent 6890N, CA, USA) equipped with a flame ionization detector (FID) and a capillary column (MEGA-10, 25 m × 0.32 mm × 0.25 μm). The column temperature program was from 150 to 200°C at 2°C/min and the injector and detector temperature were set at 250°C. Helium was the carrier gas. Identification and analysis of the peaks were done with the Agilent Technologies Chemstation A09.01 software.
2.7. Polyphenol Extraction and Analysis. Phenolic compounds from DPSO were extracted according to the method of Farrés-Cebrián et al. [20]. Extracted oils were added to ethanol 70% (1:1). The mixture was shaken vigorously for 2 min and then centrifuged (3500 rpm/5 min) and followed by 24 h at −18°C. Next, 2 ml of hexane was added and shaken vigorously for 2 min. After centrifugation (3500 rpm/5 min), the aqueous ethanolic extracts were directly analyzed.

Phenolic compounds quantification was done using liquid chromatography system (Hewlett-Packard 1100) with C-18 column (Teknokroma Tracer Exasil ODS-2, 250 mm x 4.0 mm, i.d. 5 μm). The mobile phase (0.01% trichloroacetic acid in water and acetonitrile) had the following gradient over a total run time of 55 min: 95% A initially, 75% A-30 min, 50% A-45 min, 0% A-47 min, 75% A-95 min, and 95% A-52 min until completion of the run. The quantification of the compounds was carried out by peaks integration, which was done at different wave-lengths, with reference to calibrations made using external standards.

2.8. Antioxidant Capacity. Antioxidant activity was determined by the DPPH• method [21]. 10 μl of the DPSO was added to 190 μL of DPPH• (3.8 mg/50 mL methanol), after 30 min in the dark the measurement of the absorbance was done at 517 nm. The antioxidant activity was measured by decreasing the absorbance at 517 nm (TecanInfinite M200, Männedorf, Switzerland). The antioxidant capacity was expressed as mg ascorbic acid equivalent (AEAC) per 100 g FW.

ABTS assay was determined according to Wang et al. [22]. The ABTS radical cation (ABTS•+) solution was prepared (7 mM ABTS + 2.45 mM potassium persulphate) and incubated at 23°C in the dark for twelve hours. The ABTS•+ was diluted in ethanol (80%) until an absorbance of 0.700 (±0.005) at 734 nm. 2 ml of ABTS•+ solution was added to 100 μl of the DPSO sample and mixed vigorously. The incubation was done at room temperature during 5 min and the absorbance was immediately recorded at 734 nm. The absorbance was expressed as the Trolox-Equivalent Antioxidant Capacity (TEAC).

2.9. Statistical Analysis. The average values of all the experiments were calculated and expressed as the mean value (± standard deviation). The ANOVA with post hoc SNK comparisons was performed using SPSS 16.0 for Windows.

3. Results and Discussion

3.1. Physicochemical Characterization of the Extracted Oils. Figure 2 shows the compounds of the orange peel essential revealed by GC-MS. Ten substances were identified and the summary is given in Table 1. The composition results were close to those found for samples from other geographical origin [23–25] with some detected differences. Typically, limonene was the major compound with slight differences; in our case it accounts for 94.31%. The other constituents were less than 1.7% and their order was as follows: α-terpinolene > β-myrcene > cctanal > decanal > sabinene > (E)-3-undecene > α-pine > octyl formate > valencene. Golmohammadi et al. [26] have compared the hydrodistillation with steam explosion for extraction of essential oil from orange peels and concluded that extraction process influences the limonene yield.

The orange peel essential oil was used as biosolvent for the DPSO extraction, and the efficiency was compared with petroleum ether. The physicochemical properties of the extracted oils are exposed in Table 2. Concerning the Soxhlet method, the extracted DPSO using petroleum ether had a maximum yield of 9.8% and achieved after four hours of extraction (Figure 3), and the green solvent gave a maximum oil rate of 9.25% since the second hour of extraction. The soaking method using essential oil gave the highest yield and the maximum value was 13.88% obtained after two hours of extraction (Figure 3), and the green solvent gave a maximum yield of 9.8% and achieved after four hours of extraction. The soaking method using essential oil gave the highest yield and the maximum value was 13.88% obtained after two hours of extraction (Figure 3). The oil yield extracted by petroleum ether is comparable to that found by Hamada et al. [27] (8.7–12.3% for 11 varieties of date kernels from Saudi Arabia) but lower than Tunisian Alig variety (12.73%) [28]. Petroleum ether has usually shown a high ability to extract oil in comparison with other organic solvents, such as chloroform-methanol. The efficiency of the green solvent was better in the soaking extraction method, which might be due to the dissolving power of the essential oil for
triglycerides when compared with petroleum ether. A previous study [29] has revealed that limonene is slightly more polar than hexane and could have better ability to extract oils from rice bran. In addition, the used green solvent is relatively fire- and explosion-safe, nontoxic to humans, and less volatile than hexane, and it comes from a renewable source.

Petroleum ether gave, as expected, yellow oil (Supplementary File 1) with unpleasant odor and the density was 0.87 g/cm³. In other studies, Abdalla et al. [30] have noted higher density value of oil (0.91 g/cm³) extracted from Sudan date seed variety by organic solvent. However, the DPSO extracted by the essential oil has different physical proprieties and some of them freeze at low temperature and cause trouble in the industry process [31]. In the case of oils extracted from date palm seeds, the use of essential oil could be a good practice to avoid freeze problem. For olive oil, freezing temperature variability depends on variety and olive ripeness at processing. It can be concluded that extracted essential oil used as green solvent has slightly lightened the DPSO and affected its physical appearance.

A significant effect of the extraction method on the acidity was observed. Petroleum ether gave lower acidity value (0.87 g/g) which reflects its oxidative stability during extraction [3], which is in accordance with the results obtained previously [4, 32]. The use of essential oil from orange peel was found to enhance the acid value to 1.03 and 1.01 mg/g, which is close to value of oil date seeds obtained from Libyan varieties [33]. Peroxide values were 2.96 meqO₂/kg for petroleum ether solvent and 4.26 and 5.05 meqO₂/kg for green solvent. These indices have met the quality standards and show good stability of the extracted oils. In fact, Codex Alimentarius (2009) (CODEX-STAN, 210–1999) recommends that the acid and peroxide values of cold-pressed oils should not exceed 4.0 mg/g and 15 meqO₂/kg, respectively. The low peroxide value indicates that the seed oil is fresh and is less prone to auto-oxidation. These variations may come from various factors like the unsaturation degree of the fatty acids present in the oil, storage, the light, and metals or other compounds content that can catalyze the processes of oxidation [10, 34].

3.2. Fatty Acid Analysis. Fatty acid profiles are given in Figure 4 and the percentages of fatty acids in the three-extracted DPSO are presented in Table 3. The same fatty acid profile was observed, and no significant difference was noted. Hence, the extracted DPSO are identical, and the new “green” extraction method did not change the fatty acid composition. The analysis has proven that oleic acids (C18:1) and lauric acids (C12:0) are the most abundant, followed by myristic (C14:0), palmitic (C16:0), linoleic (C18:2), and stearic acids (C18:0). However, caprylic (C10:0), palmitoleic (C16:1), and linolenic (C18:3) acids were found in small amounts. With respect to Sawaya et al. [35], they have indicated that DPSO is not a linoleic acid oil, but rather considered as an oleic-lauric oil. These results agree well with other findings previously reported by Al-Hooti et al. [36], Al showiman [37], and Devshony et al. [38]. The proportion of USAFA (unsaturated fatty acids) is important to estimate the oil oxidation [39]. Indeed, the higher the USAFA is, the more the oil is prone to oxidation. Besbes et al. [32] have reported that PUFA (polysaturated fatty acids), essentially C18:2, are usually used to assess the oil deterioration level.

ether-extracted oil might emanate from the higher temperature used during solvent recovery when essential oil is used, leading to the formation of oxidative materials, including polymers and other oil-soluble products as a result of Maillard reactions [29].

Furthermore, the physical state of DPSO at 4°C was different as only the oil obtained by petroleum ether became solid, while the others remained liquid. In fact, oils have different physical proprieties and some of them freeze at low temperature and cause trouble in the industry process [31].

![Figure 2: Gas chromatography-mass spectrometry (GC-MS) profile of the orange peel essential oil (1: alpha-pinene, 2: sabinene, 3: beta-myrcene, 4: octanal, 5: limonene, 6: octyl formate, 7: alphaterpinolene, 8: decanal, 9: (E)-3-undecene, and 10: valencene).](image-url)

Table 1: Chemical composition of essential oil extracted from orange peel.

| Constituent       | Retention time | Area (%) |
|-------------------|---------------|----------|
| 1 alpha-Pinene    | 7.068         | 0.302    |
| 2 Sabinene        | 8.014         | 0.332    |
| 3 beta-Myrcene    | 8.417         | 1.520    |
| 4 Octanal         | 8.674         | 0.533    |
| 5 Limonene        | 9.603         | 94.310   |
| 6 Octyl formate   | 10.289        | 0.290    |
| 7 alpha-Terpinolene | 11.024   | 0.533    |
| 8 Decanal         | 13.408        | 0.456    |
| 9 (E)-3-Undecene  | 14.832        | 0.326    |
| 10 Valencene      | 19.512        | 0.277    |

**Figure 2:** Gas chromatography-mass spectrometry (GC-MS) profile of the orange peel essential oil (1: alpha-pinene, 2: sabinene, 3: beta-myrcene, 4: octanal, 5: limonene, 6: octyl formate, 7: alphaterpinolene, 8: decanal, 9: (E)-3-undecene, and 10: valencene).
Table 2: Physicochemical properties of extracted seed oils.

| Solvent          | Ether petroleum | Soxhlet | Essential oil | Soaking in essential oil |
|------------------|-----------------|---------|---------------|--------------------------|
| Yield (%)        | 9.8 ± 1.02b     | 9.25 ± 1.50b | 13.88 ± 0.95a |                          |
| Color (supplementary file 1) | Yellow | Brown | Brown |                          |
| Odor             | Unpleasant      | Good    | Good         |                          |
| Density (g/cm³)  | 0.87 ± 0.11a    | 0.86 ± 0.08a | 0.86 ± 0.10a |                          |
| Physic state at 4°C | Solid | Liquid | Liquid |                          |
| Acidity (mg/g)   | 0.87 ± 0.02b    | 1.03 ± 0.31a | 1.01 ± 0.23a |                          |
| Peroxide value (meqO₂/kg) | 2.96 ± 0.61b | 4.26 ± 0.69a | 5.05 ± 0.76a |                          |

Mean and standard deviation values with the same letter within the same parameter were not significantly different (p ≥ 0.05).

Figure 3: The effect of extraction time on oil yield.

Figure 4: Fatty acid profiles of the three types of date seeds oils by gas chromatography. (a) Oil extracted by petroleum ether, (b) by essential oil with Soxhlet, and (c) by soaking in essential oil (1: capric C10:0, 2: lauric C12:0, 3: myristic C14:0, 4: palmitic C16:0, 5: palmitoleic C16:1, 6: stearic C18:0, 7: oleic C18:1, 8: linoleic C18:2, and 9: linolenic C18:3).
that terpenes have higher polarity than organic solvent as of the bioactive substances [41]. Kumar et al. [14] have noted could be attributed to the polarity, and thus the extractability (Table 4). D"hese variations between the two types of solvents Soxhlet method and 402.67 mg/100 g by the soaking method (Table 4). These variations between the two types of solvents could be attributed to the polarity, and thus the extractability of the bioactive substances [41]. Kumar et al. [14] have noted that terpenes have higher polarity than organic solvent as hexane. These authors have recommended the use of terpenes to ensure a cleaner environment, safer handling, and nontoxicity. Furthermore, phenolic profiles were not the same. More phenolic compounds were detected in the case of extraction with essential oil. Although petroleum ether gave DPSO rich in gallic and p-coumaric acids, it also provided other components with a smaller amount (o-coumaric acids, protocatechuic, chlorogenic, and 4-O-cafeoylquinic acids, which are detected with higher amounts than the gallic acid and p-coumaric acid (Table 4). Essential oil solvent offered more phenolic compounds such as protocatechuic, chlorogenic, o-coumaric, trans-ferulic, and syringic acid and flavonoids gave DPSO rich in gallic and protocatechuic acid (Table 4).

Table 3: Percentage of phenolic compound of different seed oils

| Extraction method | Ether petroleum | Soxhlet | Essential oil | Soaking in essential oil |
|-------------------|----------------|---------|---------------|--------------------------|
| Gallic acid       | 34.89 ± 4.31a | 38.20   | 23.55 ± 0.06b | 6.82                    |
| Protocatechuic acid | N.D.      |         | 82.67 ± 0.57a | 23.95                   |
| Chlorogenic acid  | N.D.         |         | 79.94 ± 6.49a | 23.16                   |
| 4-O-Caffeoylquinic acid | 0.86 ± 0.86c | 0.94   | 81.45 ± 6.61b | 23.59                   |
| Syringic acid     | 4.37 ± 0.37b | 4.78   | 10.76 ± 0.06a | 3.12                    |
| p-Coumaric acid   | 32.01 ± 0.17ab | 35.05  | 31.63 ± 0.00b | 9.16b                   |
| trans-Ferulic acid | 6.15 ± 0.06b | 6.73   | 7.62 ± 0.17b  | 2.21                    |
| Hyperoside quercetin-3-o-galactoside | 0.69 ± a | 0.76 | N.D. | N.D. |
| Rutin             | 0.63 ± 0.03a | 0.69   | 1.22 ± 0.06a  | 0.35                    |
| o-Coumaric acid   | 11.26 ± 0.11b | 12.34  | 12.44 ± 0.11a | 3.60                    |
| Apigenin-7-o-glucoside | 0.06 ± 0.06a | 0.06 | N.D. | N.D. |
| (E)-Cinnamic      | N.D.         |         | 11.69 ± 0.63b | 3.38                    |
| Naringenin        | N.D.         |         | N.D. | 35.87 ± 3.51a | 8.91 |
| Cirsilineol       | 0.40 ± 0.06c | 0.44   | 1.16 ± 0.00a  | 0.34                    |
| Acacetin          | N.D.         |         | 1.10 ± 0.29a  | 0.32                    |
| Total phenolic    | 91.32 ± 0.52c |        | 345.23 ± 8.85b | 402.67 ± 14.60a |

N.D., not detected. Mean and standard deviation values with the same letter within the same parameter were not significantly different (p ≥ 0.05).

3.3. Phenolic Compounds and Antioxidant Capacity. The current investigation demonstrated that petroleum ether solvent provided DPSO with a phenol content of 91.32 mg/100 g (Table 4). This quantity was higher than that reported by Besbes et al. [32] who found a quantity of 52.6 mg/100 g in the same variety. Green solvent was found to enhance the DPSO phenol content that became 345.23 mg/100 g by Soxhlet method and 402.67 mg/100 g by the soaking method (Table 4). The antioxidant activity had the same tendency as the phenolic content. The DPPH test showed that DPSO extracted by essential oil exhibited the highest activity (39.22 and 47.06 mg AEAC/100 g FW) (Figure 5). Similarly, ABTS assays showed that the antioxidant capacity of DPSO extracted by the soaking method had the highest value.
should be carried out to improve the yield and its compounds. However, further research investigations using a green solvent would be applied to extract more bioactive compounds from date seeds. Thanks to its polar nature, it is possible that the used solvent demonstrated its ability to extract oil from date palm seeds. This extraction method represents a promising approach for bio-oil extraction from date seeds. Besides, the comparison studies proved that this green solvent extracted higher oil amount and significantly improved its quality. The results of this study would also have broader implications for the extraction of other liposoluble compounds from date seeds. Thanks to its polar nature, it is possible that the used green solvent would be applied to extract more bioactive compounds. However, further research investigations should be carried out to improve the yield and its physicochemical properties. Future work should focus on the analysis of semivolatile compounds that could remain in the oil after essential oil evaporation.

Data Availability
No data were used to support this study.

Conflicts of Interest
The authors declare that they have no conflicts of interest.

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Supplementary Materials
The supplementary file describes the difference in color between oil extracted by petroleum ether using Soxhlet, oil extracted by essential oil using Soxhlet, and oil extracted by soaking in orange peel essential oil. (Supplementary Materials)

4. Conclusion
The use of essential oil extracted from orange peel as green solvent demonstrated its ability to extract oil from date palm seeds. This extraction method represents a promising approach for bio-oil extraction from date seeds. Besides, the comparison studies proved that this green solvent extracted higher oil amount and significantly improved its quality. The results of this study would also have broader implications for the extraction of other liposoluble compounds from date seeds. Thanks to its polar nature, it is possible that the used green solvent would be applied to extract more bioactive compounds. However, further research investigations should be carried out to improve the yield and its physicochemical properties. Future work should focus on the analysis of semivolatile compounds that could remain in the oil after essential oil evaporation.

References
[1] S. Niazi, I. M. Khan, I. Pasha, S. Rasheed, S. Ahmad, and M. Shoaib, “Date palm: composition, health claim and food applications,” Natural Products and Nanotechnology, vol. 2, no. 1, p. 9, 2017.
[2] W. Al-Shahib and R. J. Marshall, “Fatty acid content of the seeds from 14 varieties of date palm Phoenix dactylifera L.”, International Journal of Food Science and Technology, vol. 38, no. 6, pp. 709–712, 2003.
[3] S. Besbes, C. Blecker, C. Deroanne, G. Lognay, N. E. Drira, and H. Attia, “Quality characteristics and oxidative stability of date seed oil during storage,” Food Science and Technology International, vol. 10, no. 5, pp. 333–338, 2004.
[4] I. Nehdi, S. Omri, M. I. Khalil, and S. I. Al-Resayes, “Characteristics and chemical composition of date palm (Phoenix canariensis) seeds and seed oil,” Industrial Crops and Products, vol. 32, no. 3, pp. 360–365, 2010.
[5] A. Delgado, S. Al-Hamimi, M. F. Ramadan et al., “Contribution of tocots to food sensorial properties, stability, and overall quality,” Journal of Food Quality, vol. 2020, Article ID 8885865, 8 pages, 2020.
[6] E. Marinova, A. Toneva, and N. Yanishlieva, “Synergistic antioxidant effect of α-tocopherol and myricetin on the autoxidation of triacylglycerols of sunflower oil,” Food Chemistry, vol. 106, no. 2, pp. 628–633, 2008.
[7] K. H. Yuen, J. W. Wong, A. B. Lim, B. H. Ng, and W. P. Choy, “Effect of mixed-tocotrienols in hypercholesterolemic subjects,” Functional Foods in Health and Disease, vol. 1, no. 3, pp. 106–117, 2011.
[8] J. Fakhfakh, S. Ben-Youssef, M. Naushad, and N. Allouche, “Different extraction methods, physical properties and chemical composition of date seed oil,” Sustainable Agriculture Reviews, vol. 34, pp. 125–153, 2019.
[9] D. Bozdoğan Konuşkan, "Minor bioactive lipids in cold pressed oils," in Cold Pressed Oils, pp. 7–14, Elsevier, Berlin, Germany, 2020.
[10] M. Jenmi, S. Chniti, and S. S. Soliman, Fruit Oils: Chemistry and Functionality, M. Ramadan (eds), Springer, Cham, Switzerland, 2019.
[11] C. van Thriel, "Toxicology of solvents (including alcohol)," in Reference Module in Biomedical SciencesElsevier, Berlin, Germany, 2014.
[12] P. Hanmoungjai, L. Pyle, and K. Niranjan, "Extraction of rice bran oil using aqueous media," Journal of Chemical Technology and Biotechnology, vol. 75, no. 5, pp. 348–352, 2000.
[13] L. G. Costa and G. Giordano, "Polybrominated diphenyl ethers," in Encyclopedia of Toxicology, pp. 1032–1034, Elsevier, Berlin, Germany, Third edition, 2014.
[14] S. P. J. Kumar, S. R. Prasad, R. Banerjee, D. K. Agarwal, K. S. Kulkarni, and K. V. Ramesh, "Green solvents and technologies for oil extraction from oilseeds," Chemistry Central Journal, vol. 11, no. 1, pp. 1–8, 2017.
[15] P. K. Mamidipally and S. X. Liu, "First approach on rice bran oil extraction using limonene," European Journal of Lipid Science and Technology, vol. 106, no. 2, pp. 122–125, 2004.
[16] M. Virot, V. Tomao, C. Ginies, F. Visinoni, and F. Chemat, "Green procedure with a green solvent for fats and oils’ determination," Journal of Chromatography A, vol. 1196-1197, no. 1-2, pp. 147–152, 2008.
[17] A. S. Sonmezdag, H. Kelebek, and S. Selli, "Characterization of aroma-active and phenolic profiles of wild thyme (Thymus serpyllum) by GC-MS-Olfactometry and LC-ESI-MS/MS," Journal of Food Science & Technology, vol. 53, no. 4, pp. 1957–1965, 2016.
[18] D. Firestone, "Standard methods for the analysis of oils, fats and soaps for the international union of pure and applied chemistry," Journal of AOAC International, vol. 48, no. 3, pp. 686–687, 1965.
[19] I. A. Nehdi, H. Sbihi, C. P. Tan, and S. I. Al-Resayes, "Evaluation and characterisation of Citrullus colocynthis (L.) Schrad seed oil: comparison with Helianthus annuus (sunflower) seed oil," Food Chemistry, vol. 136, no. 2, pp. 348–353, 2013.
[20] M. Farrés-Cebrián, R. Seró, J. Saurina, and O. Núñez, "HPLC-UV polyphenolic profiles in the classification of olive oils and other vegetable oils via principal component analysis," Separations, vol. 3, no. 4, pp. 33–44, 2016.
[21] G. Rodríguez, R. Rodríguez, J. Fernández-Bolaños, R. Guillén, and A. Jiménez, "Antioxidant activity of effluents during the purification of hydroxytyrosol and 3,4-dihydroxyphenyl glycol from olive oil waste," European Food Research and Technology, vol. 224, no. 6, pp. 733–741, 2007.
[22] S. Wang, R. Yang, H. Li et al., "Evaluation and comparison of in vitro antioxidant activities of unsaponifiable fraction of 11 kinds of edible vegetable oils," Food Sciences and Nutrition, vol. 6, no. 8, pp. 2355–2362, 2018.
[23] S. C. Deterre, B. Rega, J. Delarue, E. Teillet, and P. Giampoli, "Classification of commercial bitter orange essential oils (Citrus aurantiumL.), based on a combination of chemical and sensory analyses of specific odor markers," Journal of Essential Oil Research, vol. 26, no. 4, pp. 254–262, 2014.
[24] J. A. Pino and A. Rosado, "Composition of cold-pressed bitter orange oil from Cuba," Journal of Essential Oil Research, vol. 12, no. 6, pp. 675–676, 2000.
[25] G. Dugo, "The composition of the volatile fraction of the Italian Citrus essential oils," Perfumer & Flavorist, vol. 19, no. 6, pp. 29–51, 1994.
epidermal keratinocytes, “International Journal of Dermatology,” vol. 49, no. 3, pp. 262–268, 2010.

[44] I. Dammak, S. Boudaya, F. Ben Abdallah, H. Turki, and H. Attia, “Effect of date seed oil on p53 expression in normal human skin,” Connective Tissue Research, vol. 51, no. 1, pp. 55–58, 2010.

[45] J. C. Espín, M. T. García-Conesa, and F. A. Tomás-Barberán, “Nutraceuticals: facts and fiction,” Phytochemistry, vol. 68, no. 22–24, pp. 2986–3008, 2007.

[46] E. Middleton, C. Kandaswami, and T. C. Theoharides, “The effects of plant flavonoids on mammalian cells: implications for inflammation, heart disease, and cancer,” 2000, http://www.pharmrev.org.

[47] A. Bendini, L. Cerretani, A. Carrasco-Pancorbo et al., “Phenolic molecules in virgin olive oils: a survey of their sensory properties, health effects, antioxidant activity and analytical methods. An overview of the last decade alessandra,” Molecules, vol. 12, no. 8, pp. 1679–1719, 2007.

[48] B. Zhu, B. Shang, Y. Li, and Y. Zhen, “Inhibition of histone deacetylases by trans-cinnamic acid and its antitumor effect against colon cancer xenografts in athymic mice,” Molecular Medicine Reports, vol. 13, no. 5, pp. 4159–4166, 2016.