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Research Article

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].

Two processes were commonly used for oil extraction from the date seeds. The first was by pressing method allowing obtaining very pure oil containing no foreign chemical substances. Despite the very low yield (≈5.5%) of this method [8], interesting minor bioactive compounds were highlighted which have beneficial effects on human health and also play an important role in prolonging the shelf life of the cold-pressed oils by the increase of oxidative stability of the oil [9]. The second process was by using an organic solvent which is recovered by various methods. Jemni et al. [10] have discussed the usefulness of several solvents in the extraction of the date palm seed oil. These authors concluded that nonpolar solvents such as toluene, chloroform, and hexane gave the best yields. After the extraction process, the oil must be completely purified to avoid the toxicity of organic solvents that had adverse effects on

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 Nefzaoua 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 m^3/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 repining 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 (4 l/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 (99.99%), 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 azeotrope 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 azeotrope 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.

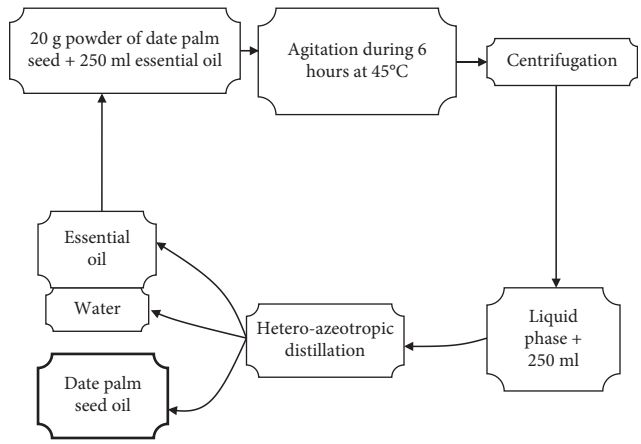

Figure 1: Extraction method by soaking in essential oil.

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 Extrasil ODS-2, 250 mm × 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 wavelengths, 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 (TecanInfininte 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 ($ABTS^{\bullet+}$) solution was prepared (7 mM ABTS + 2.45 mM potassium persulphate) and incubated at 23°C in the dark for twelve hours. The $ABTS^{\bullet+}$ was diluted in ethanol (80%) until an absorbance of 0.700 (±0.005) at 734 nm. 2 ml of $ABTS^{\bullet+}$ 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-pinene > 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). 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

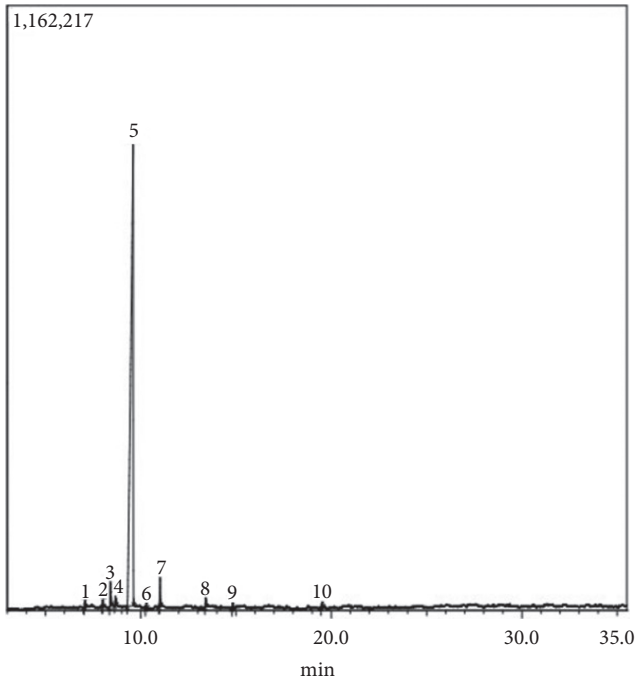

Figure 2: Gas chromatography-mass spectrometry (GC-MS) profile of the orange peel essential oil (1: alpha-pinene, 2: sabinen, 3: beta-myrcene, 4: octanal, 5: limonene, 6: octyl formate, 7: alpha-terpinolene, 8: decanal, 9: (E)-3-undecene, and 10: valencene).

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

	Constituent	Retention time	Area (%)
1	α-Pinene	7.068	0.302
2	Sabinene	8.014	0.332
3	β-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	α-Terpinolene	11.024	1.653
8	Decanal	13.408	0.456
9	(E)-3-Undecene	14.832	0.326
10	Valencene	19.512	0.277

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/cm^3. In other studies, Abdalla et al. [30] have noted higher density value of oil (0.91 g/cm^3) extracted from Sudan date seed variety by organic solvent. However, the DPSO extracted by the essential oil has different physical appearance, whose color is light brown (Supplementary File 1) with pleasant odor and density of 0.86 g/cm^3. The bio-extracted oil being slightly darker compared with petroleum 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]. 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 meqO_2/kg for petroleum ether solvent and 4.26 and 5.05 meqO_2/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 meqO_2/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 (polyunsaturated fatty acids), essentially C18 : 2, are usually used to assess the oil deterioration level.

Table 2: Physicochemical properties of extracted seed oils.

Solvent	Soxhlet		Soaking in essential oil
	Ether petroleum	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/cm^3)	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 (meqO_2/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 ($p \geq 0.05$).

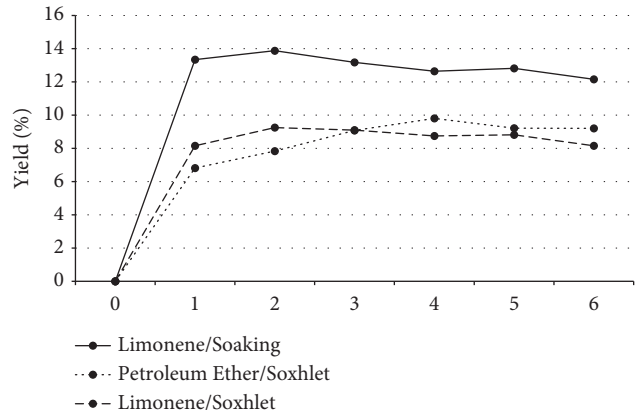

Figure 3: The effect of extraction time on oil yield.

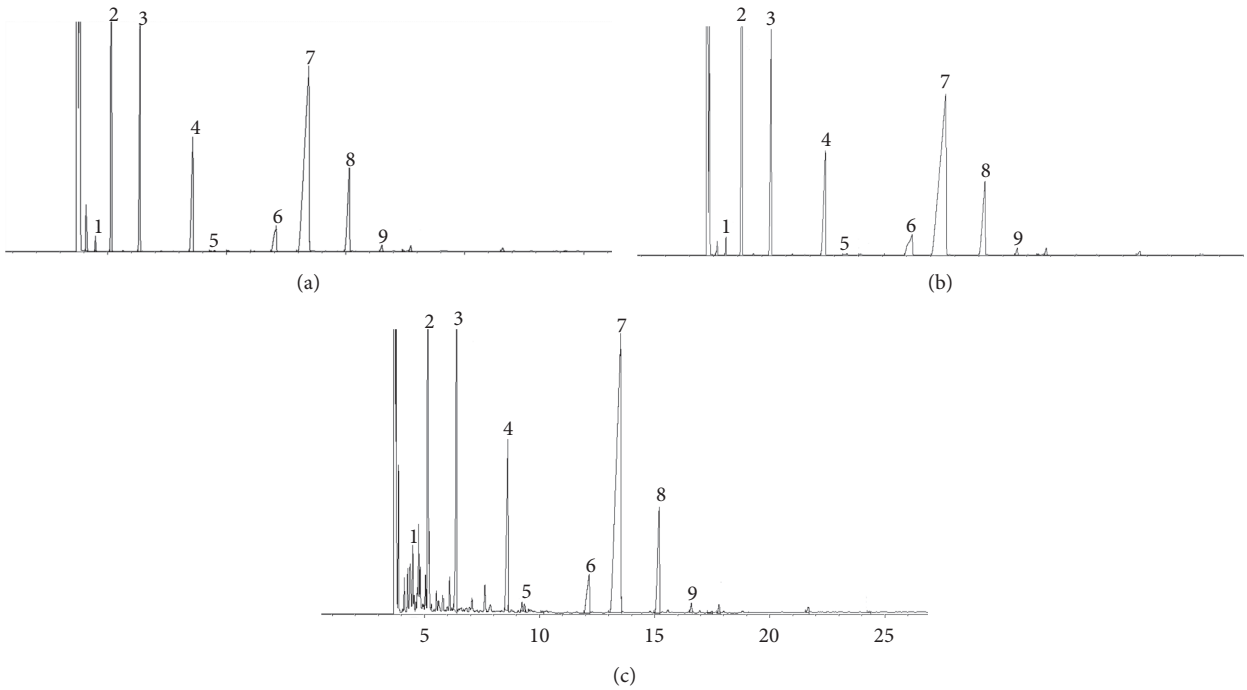

Figure 4: Fatty acid profiles of the three types of date seeds oils by gas chromatography. (a) Oil extracted by petroleum ether, (b) by essential oil with Soxhlet, and (c) by soaking in essential oil (1: capric C10 : 0, 2: lauric C12 : 0, 3: myristic C14 : 0, 4: palmitic C16 : 0, 5: palmitoleic C16 : 1, 6: stearic C18 : 0, 7: oleic C18 : 1, 8: linoleic C18 : 2, and 9: linolenic C18 : 3).

Table 3: Fatty acids composition (%) of the studied oils.

Extraction method	Soxhlet		Soaking in essential oil
	Ether petroleum	Essential oil	
Capric C10 :0	0.58 ± 0.02a	0.54 ± 0.10a	0.55 ± 0.08a
Lauric C12 :0	25.16 ± 2.01b	29.66 ± 3.44a	25.25 ± 1.54b
Myristic C14 :0	10.81 ± 1.55a	12.03 ± 2.01a	10.98 ± 0.57a
Palmitic C16 :0	8.53 ± 0.04a	8.74 ± 0.57a	8.78 ± 0.88a
Palmitoleic C16 :1	0.13 ± 0.02a	0.15 ± 0.10a	0.20 ± 0.13a
Stearic C18 :0	3.26 ± 0.55a	3.02 ± 0.89a	3.11 ± 0.99a
Oleic C18 :1	42.14 ± 2.33a	37.29 ± 1.66b	41.78 ± 2.61a
Linoleic C18 :2	8.48 ± 1.33a	7.52 ± 0.99a	8.32 ± 0.78a
Linolenic C18 :3	0.05 ± 0.05a	0.09 ± 0.11a	0.08 ± 0.10a
SAFA	48.34b	53.99a	48.67b
USAFA	50.80a	45.05b	50.38a
PUFA	8.53a	7.61ab	8.4a
MUFA	42.27a	37.44b	41.98a

SAFA, saturated fatty acids. USAFA, unsaturated fatty acids. PUFA, polyunsaturated fatty acids. MUFA, monounsaturated fatty acids. Mean and standard deviation values with the same letter within the same parameter were not significantly different ($p \geq 0.05$).

Table 4: Percentage of phenolic compound of different seed oils

Extraction method	Soxhlet				Soaking in essential oil	
	Ether petroleum		Essential oil			
	mg/100g	%	mg/100g	%	mg/100g	%
Gallic acid	34.89 ± 4.31a	38.20	23.55 ± 0.06b	6.82	20.12 ± 1.38b	5.00
Protocatchuic acid	N.D.		82.67 ± 0.57a	23.95	75.29 ± 6.15b	18.70
Chlorogenic acid	N.D.		79.94 ± 6.49a	23.16	99.71 ± 0.52b	24.76
4-O-Caffeoylquinic acid	0.86 ± 0.86c	0.94	81.45 ± 6.61b	23.59	101.45 ± 0.52a	25.20
Syringic acid	4.37 ± 0.37b	4.78	10.76 ± 0.06a	3.12	10.47 ± 0.46a	2.60
p-Coumaric acid	32.01 ± 0.17ab	35.05	31.63 ± 0.00b	9.16b	32.85 ± 0.75a	8.16
trans-Ferulic acid	6.15 ± 0.06b	6.73	7.62 ± 0.17b	2.21	10.52 ± 2.47a	2.61
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	0.58 ± 0.07a	0.14
o-Coumaric acid	11.26 ± 0.11b	12.34	12.44 ± 0.11a	3.60	11.45 ± 0.29b	2.84
Apigenin-7-o-glucoside	0.06 ± 0.06a	0.06	N.D.		N.D.	
(E)-Cinnamic	N.D.		11.69 ± 0.63b	3.38	35.87 ± 3.51a	8.91
Naringenin	N.D.		N.D.		2.44 ± 1.03a	0.61
Cirsilineol	0.40 ± 0.06c	0.44	1.16 ± 0.00a	0.34	0.70 ± 0.23b	0.17
Acacetin	N.D.		1.10 ± 0.29a	0.32	1.22 ± 0.06a	0.30
Total phenolic mg/100 g	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 ($p \geq 0.05$).

In our study and for all the extracted oils, PUFA values were around 8% which are lower than the previous findings by Besbes et al. [32] and by Tafti et al. [40], who found 14.1% and 14.08% of PUFA, respectively.

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). 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, trans-ferulic, and syringic acid and flavonoids components) (Table 4). Essential oil solvent offered more phenolic compounds such as protocatechuic, chlorogenic, and 4-O-caffeoylquinic acids, which are detected with higher amounts than the gallic acid and *p*-coumaric acid (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

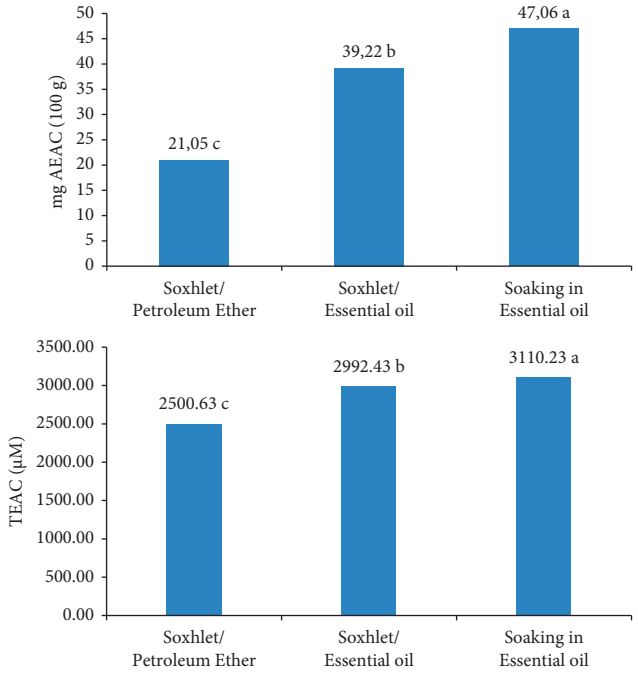

Figure 5: Antioxidant activity expressed as mg AEAC/100 g and TEAC μmol/l DPSO.

(Figure 5). Herch et al. [42] have studied the antioxidant capacity of flesh oil from the Kintichi variety and attributed the high antioxidant activity to the high phenolic content. DPSO extracted by green solvent was subjected to screening for its higher antioxidant activity and higher phenolic content. Polyphenols are natural antioxidants that offer this product the ability to repair the human skin [43]. Many studies proposed the DPSO as an ingredient of UV protector products [4, 44]. Many biological effects were attributed to phenolic compounds, including antibacterial and anticarcinogenic [45, 46]. Chlorogenic acids, which are detected only in the green extraction, prevent degenerative pathologies such as cardiovascular diseases and cancer [47]. (E)-Cinnamic acid that is also extracted only by the green method has a large spectrum of biological activities such as anti-inflammatory and anticancer properties. Furthermore, it has been detected as gut microbe-derived metabolites exerting various biological effects in the colon [48].

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.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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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*)

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