

# Comparison of Physicochemical Characteristics, Phytochemical Composition, and Antioxidant Capacity of Two Oils Extracted from Jihel Date Kernel (*Phoenix dactylifera* L.) Varieties Cultivated in Zagora

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**Abstract:** This study aims to analyze and characterize two different vegetable oils that were extracted from the kernels of Jihel date palms grown in the Zagora province of South East Morocco. The date pits are subjected to drying and grinding, and the resulting powder is extracted with hexane using two different methods: decoction and soxhlet extraction. The yields obtained were 8.03% and 10.75%, respectively. The analysis of the oils using GC-MS revealed that oleic acid (44.90-44.99%) constituted the most prevalent fatty acid, succeeded by lauric acid (19.43-20.18%). Saturated fatty acids accounted for 46.60-48.01% of the total content of fatty acids, while unsaturated fatty acids represented 51.59-52.61%. The overall sterol content in the oils obtained by Soxhlet and Decoction was 3589 and 3560 mg/kg, respectively. In both oils,  $\beta$ -sitosterol was the primary sterol, accounting for 64.3% and 63.9% of the total amount of sterol in the decoction and soxhlet-extracted oils, respectively.  $\gamma$ -tocopherol was the main constituent, with a range of 52.99-57.32%. The total phenol content varied between 52.98 mg Eq AG/g d.m for the soxhlet-extracted oil and 26.68 mg Eq AG/g d.m for the oil obtained by decoction. In our study, the oil extract's ability to scavenge DPPH radicals was ( $IC_{50}$ : 0.155 and 0.310 mg/mL). These findings imply that our date kernel oil is a valuable natural antioxidant source and may be used as a functional food formulation or cosmetic ingredient.

**Keywords:** *Phoenix dactylifera*; date pits; Jihel; antioxidant; oleic acid;  $\gamma$ -tocopherol;  $\beta$ -sitosterol.

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## 1. Introduction

The Middle East and North Africa are widely accessible regions for date palms (*Phoenix dactylifera*) [1]. Morocco currently holds the twelfth position among the world's largest producers of dates, with the date palm industry making up to 60% of agricultural production in oases [2]. This industry provides employment to almost 2 million people, generating 3.6 million working days and contributing nearly 2 billion DH in annual revenue, with an added value of 1.4 billion DH [3]. Date palm (*Phoenix dactylifera* L.) is a highly significant crop cultivated in diverse regions worldwide. The edible part, the pulp, which also includes dietary fiber, has 81–88% sugars, primarily fructose, glucose, and sucrose, along with dietary fiber (5-8.5%) and limited quantities of protein, pits, ashes, and polyphenols [4]. These trees produce a lot of agricultural waste, such as dry leaves, seeds, and other materials [5]. Date pits, commonly considered waste or utilized as animal feed, may contain

valuable components that can be extracted [6]. Extensive research has been conducted on their chemical composition, which predominantly comprises dietary fiber, carbohydrates, protein, phenolic compounds, and minerals [7]. These components play diverse biological roles, including antioxidant, antibacterial, anti-inflammatory, and antiviral activities, improving hyperglycemia and hyperlipidemia [8,9]. Among these components, oils and fats play a crucial role in providing essential energy to humans and enhancing the sensory attributes of food [10]. Among the date seed's most intriguing ingredients is oil. Recently, there has been a growing emphasis on enhancing the functional and nutritional attributes of vegetable oils, the greatest source of dietary fats [11]. Date seeds represent a valuable oil source, containing approximately 5 to 13%, characterized by its abundance in phenolic compounds, tocopherols, and phytosterols [6,12–15]. Previous researchers have examined the composition of date seed oil, revealing its richness in vitamins, minerals, fatty acids, phenolic compounds, and antioxidants, rendering it valuable for incorporation into food formulations [15–17]. In order to enhance the valorization of the kernels of the Moroccan species Jihel, which constitutes over 50% of the Zagora region's total production [18] and are often thrown away as waste, we conducted a study on the physicochemical characteristics, phytochemical composition, and antioxidant potential of the Jihel cultivar's kernel oils.

## 2. Materials and Methods

### 2.1. Plant material.

The Jihel date a merchant transports palm fruits from the southeastern region of Morocco to the province of Zagora. According to Köppen-Geiger, Zagora experiences hot, dry summers due to its temperate Mediterranean climate. At an altitude of 733 meters, The average yearly temperature of Zagora is 19.5°C, with 161.9 mm of rainfall [19]. After separation from the pulp, the pits are stripped of their pericarp, a thin envelope surrounding them.

### 2.2. Methods.

#### 2.2.1. Preparation of the kernel powder.

The cores were dried in an oven set to 60°C for the entire night. The cores were ground with a heavy-duty grinder, and the powder was obtained and then sieved through a 200 µm sieve.



**Figure 1.** Date of Jihel variety.



**Figure 2.** Jihel date stone powder.

## 2.2.2. Vegetable oil extraction from the kernels.

### 2.2.2.1. Extraction of vegetable oil from the kernels by Soxhlet.

Total lipids were isolated from the nucleus using the soxhlet equipment and hexane. It took 6 hours to extract the material. A rotating evaporator was employed to evaporate the solvent at low pressure; the resultant oil was then gathered, weighed, and kept in a dark container inside the refrigerator (+4°C) for further investigation [20].

### 2.2.2.2. Extraction of vegetable oil from the kernels by decoction.

A 500 mL ground-in flask is filled with 350 mL of hexane along with 100 g of core powder. After being brought to reflux for 20 minutes, the liquid is left to stir for 6 hours. The combination is then filtered, and the leftover material is saved. The filtrate is vacuum-evaporated, and the resultant oil is measured and then kept in a sterile dark glass bottle before being refrigerated (+4°C) for further analysis [20].

### 2.2.3. Physico-chemical analysis of vegetable oil from date pits.

The physicochemical analysis of the date palm kernel oil focused on three key indexes: the acid index, the saponification index, and the peroxide index. These indexes were determined using AFNOR methods, specifically AFNOR NFT 60-20418, AFNOR T60-20619, and AFNOR NFT 60-22 20. Milligrams of potassium hydroxide (KOH) per gram of oil were used to express the results for the acid and saponification indexes and in active oxygen milliequivalents per kilogram for the peroxide index.

### 2.2.4. Composition of fatty acids.

The fatty acid composition was assessed through gas chromatography, where methyl esters of fatty acids were analyzed following the ISO 5508 method guidelines. A Varian CP-3800 gas chromatograph fitted with a Wax 52CB CP type column (30 m long, 0.25 mm diameter) and a flame ionization detector (FID) were used to conduct the analysis. The column temperature ranged from 170°C at the start to 230°C at the finish, with a gradient of 4°C/min. The injector and detector temperatures were both set at 230°C. Data processing was carried out using Varian Star Workstation version 6.30, and the results were presented based on the relative percentage of each fatty acid type in the sample.

### 2.2.5. Sterol composition.

The ISO 6799 (1991) standard was used to determine the sterol content. Prior to the gas

chromatography analysis, the fraction of crude sterol underwent trimethylsilylation. The Varian 3800 system, which has a 30 m length and 0.25 mm diameter, was equipped with a VF-1 ms column for the analysis. As the carrier gas, 1.6 milliliters per minute of helium were used. A thermostat controlled the temperature of the column to stay at 270°C while the injector and detector were heated to about 300°C. Data from the analysis underwent processing with Varian Star Workstation v 6.30.

#### 2.2.6. Tocopherol composition.

High-performance liquid chromatography (HPLC) was employed to quantify tocopherols, following the specifications outlined in the ISO 9936:2016 standard. 250 mg of oil was dissolved in 25 mL of n-heptane to prepare the HPLC analysis solution for tocopherols. The analysis utilized a fluorescence detector with 330 nm detection and 290 nm excitation wavelengths, a 25 cm by 4 mm C18-Varian column manufactured by Varian Inc. in Middelburg, the Netherlands, and Shimadzu CR8A instruments from Champ/Marne, France. The eluent consisted of a 1.2 mL/min mixture of 99:1 isooctane to isopropanol (V/V).

#### 2.3. Carotenoids and chlorophylls.

The protocol described by Minguez Mosquera [21] is adopted to estimate the pigment content (chlorophylls and carotenoids) of our samples. For this purpose, 3g of kernel oil is filtered and introduced into 10 mL flasks. After adjusting the volume with cyclohexane, The sample's absorbance is assessed at a wavelength of 670 nm (for chlorophylls) and at 470 nm (for carotenoids) compared to a control tube containing only cyclohexane. The subsequent formulas are employed to calculate the levels of carotenoid and chlorophyll:

$$\text{Chlorophyll (ppm)} = (A_{670} \times 106) / (613 \times 100 \times l)$$

$$\text{Carotenoids (ppm)} = (A_{470} \times 106) / (2000 \times 100 \times l)$$

Or:

$A_{\lambda}$ : absorbance at wavelength  $\lambda$ .

I: thickness of the cell in centimeters(1cm).

613: specific coefficient of pheophytin as standard.

2000: Specific coefficient of lutein as a standard.

#### 2.4. Dosage of polyphenols and flavonoids.

##### 2.4.1. Extraction of total phenols from kernel oil.

The procedure outlined by Ollivier *et al.* [22] was followed in order to extract all phenolic compounds with some modifications. 0.5 g of date seed oil and 0.5 ml of an 80/20 v/v methanol/water solution were combined in a centrifuge tube. The tubes were centrifuged for 15 minutes at 500 g to recover the methanol phase after 10 minutes of vigorous mixing. To guarantee proper CPT extraction, this procedure was generally carried out twice more (for a total of three times). The volume was diluted with an 80/20 v/v methanol/water solution to 1.5 ml.

##### 2.4.2. Total polyphenol content.

The analytical procedure was adapted from the method described in the study by Singleton and Rossi [23]. The analysis began with adding 0.4 mL of date pit oil, 1.6 mL of a 7.5% sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>) solution, and 10% Folin-Ciocalteu reagent. The blend was

left undisturbed at ambient temperature for a duration of 30 minutes. The resultant solution was then subjected to absorbance measurement at a wavelength of 765 nm using visible spectrophotometry. The solution's content was determined by calculating it in milligram equivalents of gallic acid.

#### 2.4.3. Total flavonoid content.

The process characterized by Dewanto *et al.* [24] was followed in order to determine the total flavonoids. An aqueous extract with 0.01 g/mL of dry matter was added to a 10 mL volumetric flask to fill it to about 1 mL with the extract. This was combined with 5 mL of distilled water and 0.3 mL of a 5% NaNO<sub>2</sub> solution. 0.6 mL of a 10% aluminum chloride (AlCl<sub>3</sub>) solution was added after five minutes. After standing for an additional five minutes, 10 mL of distilled water was added to the mixture along with 2 mL of a 1 M NaOH solution. The findings were given in milligrams of equivalent catechin per gram of dry plant material.

#### 2.5. Evaluation of antioxidant capacity by the DPPH• radical.

The antioxidant capacity was assessed following the protocol outlined by Bondet *et al.* [25]. Before the analysis, a 0.1 mM DPPH• solution was made in methanol and kept at 4°C in the dark to assess the level of antioxidant activity. For thirty minutes, the samples were kept out of the light. Then, 3.5 mL of the DPPH• solution was combined with 0.5 mL of the diluted methanolic extract. After that, the samples' absorbance was calculated at a wavelength of 515 nm. The antioxidant activity values show how well the antioxidants scavenge the radicals produced by DPPH.

IC<sub>50</sub> (50% radical inhibition concentration) is the extract's concentration at which free radicals can be reduced by 50%. The antioxidant capacity is inversely proportional to the free radical concentration when it reaches 50%. The molecule with a lower IC<sub>50</sub> presented a high antioxidant activity [26].

### 3. Results and Discussion

#### 3.1. Yield of vegetable oil extraction.

The oil content of date kernels is shown in Table S1. Oil from date palm kernels was extracted using two techniques. Table S1 displays the yield attained by the two extraction methods chosen. The sample extracted by the soxhlet method had the highest oil yield of 10.75%, almost 3% more than that extracted by decoctions at 8.03%. These are significantly better results than those that Bouhlali *et al.* released. [27], and close to the study reported by Nehdi *et al.* [15] and Ourradi *et al.* [28]. According to this analysis, date pits cannot be classified as oil seeds like nigella, safflower, and hemp, which contain 30-40% oil. The Soxhlet extraction method is known for its ability to boost the yield of oil extraction compared to the decoction oil extraction method.

**Table 1.** The oil yield of the two extraction methods.

Method	Oil content (%)	
	Hexane	Special characteristics
Soxhlet	10.75	Dark yellow oil, viscous (15-30°C)
Decoction	8.03	Pale yellow oil, viscous (15-30°C)

This may be due to the fact that in the Soxhlet method, the solvent is renewed after each cycle, allowing even more oil to be extracted as the extraction time is extended until plant  
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material is depleted. Yield stabilizes after a number of cycles. In other ways, the solvent of the decoction oil extraction method does not renew itself and becomes saturated with oil after the first few hours of extraction, resulting in a lower yield [29].

### 3.2. Physicochemical characteristics.

Table 2 presents the acid number, saponification number, and peroxide number of date stone oils. The acid number was found to range between 0.96 (obtained through Soxhlet extraction) and 1 mg KOH/g of oil (for extraction by decoction). Our results closely align with those highlighted by Bouhlali *et al.* [27] and Herchi *et al.* [30], indicating that both oils are of good quality. The acid values obtained are within the permissible limit of 4.0 mg KOH/g of oil, indicating their satisfactory quality [31]. The saponification index provides information on the nature of the fatty acids. Depending on the extraction method used, our kernel oil's saponification value ranges from 215 to 222.74 mg KOH/g of oil. For the Soxhlet method, the saponification value is in the range of 215 mg KOH/g of oil, while for the decoction method, it is around 222.74 mg KOH/g of oil. These results align with the findings indicated by Bouhlali *et al.* [27] and Boukouada *et al.* [32]. The elevated saponification value of date stone oil suggests that date stone oils could also replace some conventional oils in detergents and shampoos after hydrogenation [33,34]. The obtained values of the oil peroxide index are 3.3 to 11.2 meq O<sub>2</sub>/kg oil for Soxhlet and Decoction, respectively. The high peroxide value of the decoction method (11.2 meq/kg) indicates that the decoction oil underwent auto-oxidation during extraction.

**Table 2.** Physicochemical properties, chlorophylls, and carotenoid content extracted from two methods of date seed oil.

Physicochemical Characteristics	Soxhlet method	Decoction method
Yield (%)	10.75	8.03
Acid number (mg KOH/g oil)	0.96	1.00
Saponification index (mg KOH/g oil)	215	221
Peroxide index (Meq O <sub>2</sub> /kg oil)	3.3 (± 0.7)	11.2 (± 2.4) meq/kg
Peroxide value (active oxygen equivalent)	26.2 (± 5.7) µg OA eq/g	89.5 (± 18.9) µg OA eq/g
Chlorophylls (mg/kg)	11.63	3.80
Carotenoids (mg/kg)	8.56	1.51

### 3.3. Chlorophylls and carotenoid contents.

The special properties of carotenoids serve as the foundation for their diverse functions and actions across various living organisms [35]. Carotenoids are associated with numerous health advantages, including a lower risk of obesity, diabetes, and certain cancers and reduced overall mortality, as evidenced by their dietary intake and circulating levels [36]. They can also function as light filters, reducing light exposure and preventing oxidative stress [37]. Date oil contains a significant amount of carotenoid pigments, giving it a very intense yellow color [38]. Also, compared to other vegetable oils, date stone oils are a potential source of carotenoids and chlorophylls; Pumpkin seed oil [39] (0.25 mg/kg Carotenoids) and (0.46 mg/kg chlorophyll), Avocado oil [40] (0.77 mg/kg Carotenoids) and (0.54 mg/kg chlorophyll). The results of carotenoids and chlorophyll contents of date seed oils are summarized in Table 2. Carotenoid contents ranged from 8.56 to 1.51 mg/kg, while chlorophylls ranged from 11.63 to 3.80. The

soxhlet extract had the highest concentrations, while the decoction extract recorded the lowest. This can be explained by the thermal effect, which results in the degradation of these pigments. Our results are a little lower than those of Herchi *et al.* [30], which is 11.24 mg/kg of oil in carotenoids, and higher in chlorophylls, which is 11.63 mg/kg.

#### 3.4. Polyphenol and flavonoid contents and antioxidant activity assessment.

The environment in which plants are grown affects the plants' presence of phenolic metabolites. Naturally occurring phenolic compounds may help heal gastric ulcers, prevent *Helicobacter pylori* infection, or prevent harmful lipid peroxidation in the stomach [41]. The content of these compounds can vary between different plant species and within the same species. Additionally, plants grown in more challenging or hostile environments tend to have higher concentrations of specific phenolic compounds [42]. Two techniques were used to evaluate how various extraction techniques affect the Jihel variety date kernels' total phenolic content and antioxidant capacity. The total polyphenol and flavonoid contents obtained from oil extracted using Soxhlet are 52.98 mgEGA/g of oil and 8.87 mgEC/g of oil, respectively, and for decoction extraction are 26.68 mgEGA/g of and 6.63 mgEC/g of oil respectively. The result in Table 3 shows that the polyphenol content of the oil extracted by Soxhlet seems to be the best method for extracting total polyphenols from date seed oil. This may be due to the Soxhlet's exhaustive extraction capacity [43].

Oils' ability to scavenge the DPPH• radical was assessed by determining their IC<sub>50</sub> value. The IC<sub>50</sub> value indicates the oil concentration required to reduce the absorbance of the DPPH• radical solution at 517 nm in half [44].

The IC<sub>50</sub> values were 0.155 and 0.310 g/L for the oil obtained by Soxhlet and by decoction, respectively. Soxhlet oil, which has the highest antioxidant activity, had the lowest value, while the oil obtained by decoction had the highest IC<sub>50</sub> value (lowest antioxidant activity). The oil extracted by Soxhlet has an antioxidant capacity 2 times greater than that expressed by the oil extracted by decoction. This result supports the higher phenolic content for the oil obtained by Soxhlet. Our results are significantly higher than those of Boukouada *et al.* [32], who reported that the total phenol contents and IC<sub>50</sub> ranges were 0.64 to 1.27 mg/g and 0.155-0.310 mg/ml, respectively. The sensitivity to oxidation of soxhlet oil, lower than that of decoction oil, is probably due to its high content of phenolic compounds. Indeed, the quality of the extracted oil is affected by temperature and extraction technique over time.

Through a comparison of the antioxidant capacity of our extracts with that of ascorbic acid, it can be inferred that these extracts have the potential to serve as antioxidants, offering an alternative to the use of ascorbic acid.

**Table 3.** Content of polyphenols, flavonoids, and antioxidant capacity of date stone oil.

Total polyphenols	Soxhlet Method	Decoction Method	Ascorbic acid
Polyphenols (mg EAG/g of oil)	52.98	26.68	
Flavonoids (mg EC/g of oil)	8.87	6.63	
IC <sub>50</sub> (mg/mL)	0.155	0.310	0.009

#### 3.5. Fatty acid composition.

Lipids, along with proteins and carbohydrates, are one of the three basic components of biological matter. FA is a major component that has a variety of roles in humans and other animals [45]. Furthermore, the fatty acid content of an oil can be used to determine its stability, physical characteristics, and nutritional value [46-48]. Table S4 displays the analysis's findings

of the fatty acids of date stones, which show a certain variation between the two types of extraction retained to examine the chemical composition of the vegetable oils of the stones of Jihel dates.

The oils extracted from the kernels of the Jihel date palm contained 11 different fatty acids. Table S4 shows the specific percentages of each fatty acid. Lauric, myristic, palmitic, stearic, caprylic, capric, and arachidic acids are the saturated fatty acids that have been identified.

**Table 4.** Fatty acid composition of oils extracted from Jihel date pits.

Fatty acid	Soxhlet	Decoction
C8:0 Caprylic acid	0.48 (± 0.26) %	0.46 (± 0.25) %
C10:0 Capric acid	0.40 (± 0.24) %	0.40 (± 0.24) %
C12:0 Lauric acid	19.43 (± 1.43) %	20.18 (± 1.46) %
C14:0 Myristic acid	10.74 (± 1.08) %	11.23 (± 1.10) %
C16:0 Palmitic acid	10.36 (± 1.06) %	10.50 (± 1.06) %
C18:0 Stearic acid	4.04 (± 0.68) %	4.13 (± 0.68) %
C20:0 Arachidic acid	0.57 (± 0.28) %	0.57 (± 0.28) %
SFA	45.45 (± 2.14) %	47.47 (± 2.52) %
C18:1 Oleic acid	44.99 (± 2.16) %	44.90 (± 2.16) %
C20:1 Gondoic acid	0.37 (± 0.23) %	0.37 (± 0.23) %
MUFA	45.36 (± 2.18) %	45.27 (± 2.17) %
C18:2 Linoleic acid	7.26 (± 0.89) %	6.26 (± 0.83) %
C18:3 $\alpha$ -linolenic acid	0.32 (± 0.02) %	0.06 (± 0.12) %
PUFA	7.58 (± 0.91) %	6.32 (± 0.83) %
U/S	1.16 %	1.08%

Lauric acid was the main constituent of saturated fatty acids, with percentages of 19.43 and 20.18% for the extraction by Soxhlet and by decoction, respectively, followed by myristic (10.74-11.23%), palmitic (10.36-10.50%) and stearic acid (4.04-4.13%). On the other hand, oleic acid was the most abundant unsaturated fatty acid, accounting for 44.99 and 44.90% of the total by Soxhlet and decoction extraction, respectively. For linoleic acid, the contents were 7.26 and 6.26% for Soxhlet and decoction, respectively. Both oils contained very small amounts of linolenic acid, not exceeding 0.5%.

These findings are consistent with earlier research (Besbes *et al.* [6], Boukouada *et al.* [32], Bouhlali *et al.* [27]). However, Kirthy *et al.* [49] found that the amount of oleic acid in date stone oil was higher (51.45%).

It can be seen from the result of this fatty acid composition that the SFA rate of the oil extracted by decoction is slightly higher by about 2% compared to that of the oil extracted by Soxhlet. For the two oils studied, the MUFA rate is the same. Regarding the rate of PUFAs, that of the oil extracted by decoction is slightly lower by approximately 1%, which could be caused by the heating temperature because PUFAs are sensitive to heat. Oleic acid is particularly efficient in lowering the risk of infection and cardiovascular disease [50,51]. Moreover, its consumption has been linked to enhanced pancreas and liver functioning, along with a decreased risk of developing gastric-duodenal ulcers. In addition, MUFAs have the power to change the composition of lipoproteins and plasma lipids, which can improve blood pressure and glucose regulation while reducing oxidative stress, coagulation, and inflammation [52]. The unsaturated/saturated fatty acid ratio, or U/S ratio, had values of 1.08 for decoction and 1.16 for soxhlet oil. These numbers show that there was no dominant class of fatty acids.

3.6. Phytosterol composition.

Natural sterols, called phytosterols, are abundant in plants and serve a number of physiological purposes. Among these functions is the reduction of cholesterol absorption, which has attracted much interest [53]. One of the crucial elements of the unsaponifiable fraction is the sterol. These are plant-derived antioxidant chemicals that give the oils high nutritional value [54]. Table S5 presents the composition and sterol content of Jihel date stone oil. Both oils exhibited high levels of sterols (3589 mg/kg) for decoction oil and (3560 mg/kg) for Soxhlet oil. The average sterol content of date stone oils was found to be greater than that of extra virgin olive oil, with a value median of ~1500 mg/kg [55], and argan oil (UnroastedCosmetic) with a value of 2150 mg/kg [56]. Together, The three main components comprising about 90% of all sterols were campesterol,  $\beta$ -sitosterol, and  $\Delta$ -5-avenasterol. Numerous researchers have highlighted the potential of consuming foods fortified with phytosterols to reduce low-density lipoprotein (LDL) cholesterol levels. LDL cholesterol is a cardiovascular disease risk factor that can be changed [53,55,57].

**Table 5.** Phytosterols composition of date kernel oil in mg/kg of oil.

Phytosterols	Soxhlet	Decoction
24-Methylen-cholesterol	1.0 %	1.2 %
$\beta$ -sitostérol	63.9 %	64.3%
Campestérol	11.6 %	10.9%
Cholesterol	0.6 %	ND
Clerosterol	1.4 %	1.7%
$\Delta$ -5,24-stigmastadienol	1.2 %	1.3%
$\Delta$ -5-avenasterol	14.4 %	14.9%
$\Delta$ -7-avénasterol	0.4 %	ND
$\Delta$ -7-stigmasténol	0.4 %	0.3%
Sitostanol	0.7 %	0.6%
Stigmasterol	4.1 %	4.3%
Total Sterols	3560 mg/kg of oil	3589 mg/kg of oil
Total sterols %	99.7	99.5

In the two types of extractions studied, the main sterols found are  $\beta$ -sitosterol (63.9%) followed by  $\Delta$ -5-avenasterol (14.4%) and campesterol (11.6%). In addition,  $\beta$ -sitosterol is abundantly present in sesame, pumpkin seed, red onion seed, cactus, and olive oil [39,58–60].  $\beta$ -sitosterol has been the most extensively researched of any sterol in terms of positive and physiological impacts on human health, which possesses anticancer qualities against lung, stomach, colon, prostate, breast, and leukemia cancers. Research has shown that  $\beta$ -sitosterol disrupts various cellular signaling pathways, including those that control invasion, apoptosis proliferation, angiogenesis, survival, and metastasis. Additionally, without causing appreciable toxicity, Pharmacological screening demonstrated effects that were antidiabetic, cardioprotective, hepatoprotective, anticancer, and anti-inflammatory [61]. The contents of our samples are higher than those reported by Nehdi *et al.* [15] (3360 mg/kg) and comparable to those detailed by Besbes *et al.* [6] (3500 mg/kg). Based on the findings of the date kernel oil's phytosterol composition, which is outlined in Table S5 above, the contents are almost identical.

3.7. Composition in Tocopherols.

Tocopherols are highly beneficial for human health because of their significant antioxidant properties and effectiveness in combating free radicals. The composition of the active ingredients in vitamin E and the composition of fatty acids and sterol profiles are crucial distinguishing factors when identifying different vegetable oils [62]. Vitamin E consists of four

tocopherols and four tocotrienols, categorized as  $\alpha$ -,  $\beta$ -,  $\gamma$ -, and  $\delta$ -forms. These tocopherols are specifically synthesized in photosynthetic organisms such as cyanobacteria, algae, and plants. Conversely, animals need to obtain them through their diet. [63]. Tocopherols can benefit health by avoiding specific cancers, heart disease, and other chronic illnesses [64-66]. Furthermore, the tocopherols found in seed oils are crucial as they protect against oxidative degradation of polyunsaturated fatty acids in plant material. Lipophilic antioxidants are naturally occurring antioxidants found primarily in vegetable oils [58]. Among the two date oils investigated,  $\gamma$ -tocopherol was identified (table S6) as the primary component, constituting approximately 52.99 and 57.32% of the total tocopherols for the soxhlet and decoction oils. According to a growing body of tocopherol research,  $\gamma$ -tocopherol may play an equal or greater function in preventing age-related illnesses, including Alzheimer's, heart disease, and cancer, according to a growing body of tocopherol research [67]. Meanwhile,  $\alpha$ -tocopherols accounted for 42.46% of decoction oil and 46.77% of soxhlet oil. However, these findings contradict the results reported in previous studies carried out by Nehdi *et al.* [15] and Besbes *et al.* [6], where  $\alpha$ -tocopherol was the main one.

The tocopherol profile of our samples is higher than those reported by Boukouada *et al.* [32], who have found that total tocopherol contents varied between 0.53 and 1.41 mg/kg for Degla- Baïdha and Tafezouine, respectively. The oils extracted from the stones of Jihel dates by these two classic techniques are found to be low in tocopherols, and the results summarized in Table 6 above show that the tocopherol content of the Decoction oil is a little high (2 mg) that that of extraction by Soxhlet.

**Table 6.** Tocopherols (mg/ kg of oil) content of date seed oil extracted using two different methods.

Tocopherols	Soxhlet method	Decoction method
(a) Vitamin E ( $\alpha$ -tocopherol)	8.28 ( $\pm$ 0.132) mg/kg	8.11( $\pm$ 0.134) mg/ kg
(a) Vitamin E ( $\beta$ -tocopherol)	<5 (LOQ) mg/ kg	<5 (LOQ) mg/ kg
(a) Vitamin E ( $\delta$ -tocopherol)	<5 (LOQ) mg/ kg	<5 (LOQ) mg/ kg
(a) Vitamin E ( $\gamma$ -tocopherol)	9.38 ( $\pm$ 0.188) mg/ kg	10.95 ( $\pm$ 0.158) mg/ kg
Total tocopherols	17.7 mg/ kg	19.1 mg/ kg

#### 4. Conclusion

The food and cosmetic industry's need for raw natural vegetable materials to meet consumer requirements and quality standards has prompted us to evaluate the phytochemical composition, physicochemical characteristics, and antioxidant power of vegetable oils extracted from Jihel date pits. Determining the physicochemical parameters of the two oils, particularly the acid index, the peroxide index, and the saponification index, allows us to conclude that these parameters are within the standards. The organoleptic characteristics show that these oils are of good quality. The chemical composition in fatty acids of these two oils reveals the presence of unsaturated fatty acids, oleic acid  $\omega$ -9 (44.90-44%), linoleic acid  $\omega$ -6 (6.26-7.26%), and linolenic acid  $\omega$ -3 (0.5%), with a total proportion of 51.59-52.62%, which allows us to classify them among oils of the oleic/linoleic type. The phytosterol contents of both oils register the presence of  $\beta$ -sitosterol in a large proportion (about 64%). These oils analyzed in tocopherols (17.7-19.1 mg/kg), in phenolic compounds (52.98-26.68 mg EAG/g), in flavonoids (8.87-6.63 mg EC/g), in carotenoids (8.56-1.51 mg of  $\beta$ -carotene /kg of oil) and chlorophyll (11.63-3.80 mg/kg of oil ) give these vegetable oils an adequate antioxidant activity. This has been proven by the DPPH• test (IC50: 0.155 and 0.310 mg/mL) that we have made.

This composition calls for a high level of valorization of this by-product, and it suggests

using this oil as an ingredient in pharmaceuticals, cosmetics, and other formulations (moisturizing creams or as massage oil), as well as for nutritional purposes due to the high antioxidant capacity of date pits oil.

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## Conflicts of Interest

The authors declare no conflict of interest.

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