https://doi.org/10.48047/AFJBS.6.15.2024.12098-12113

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

In Vitro Evaluation of Antioxidant Activity and Phytochemical Composition of Date Seed Extracts (Phoenix dactylifera L.) from the Algerian 'Deglet Nour' Variety

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Volume 6, Issue 15, Sep 2024

Received: 15 July 2024

Accepted: 25 Aug 2024

Published: 25 Sep 2024

doi: 10.48047/AFJBS.6.15.2024.12098-12113

Abstract
Valorizing food waste is crucial in pharmaceuticals and medicine due to its active principles. Date seeds, a byproduct of Algerian date processing, were evaluated for their phytochemical content using four extraction methods: decoction for the aqueous extract (AE) and maceration for hydro-methanolic (HME), hydro-ethanolic (HEE), and hydro-acetone (HAE) extracts. Phytochemical analysis revealed all extracts to be rich in phenols, flavonoids, tannins, and quinones. The HAE 80% extract was most effective for total phenols (1000 mg), showing significant differences ($P < 0.05$) from other extracts. Similarly, HAE 80% showed significant differences ($P < 0.05$) in flavonoid content, while tannin concentrations varied significantly ($P < 0.05$) among HEE 80%, AE, and HAE 80%. Antioxidant activity, assessed via FRAP and DPPH methods, showed slight differences ($P \leq 0.05$) among AE, HAE, and HME, with HAE exhibiting the highest scavenging effect (IC50 = 2.60±0.55 µg/ml), comparable to Trolox (2.56±0.57 µg/ml). AE showed the lowest scavenging effect in the TAC test (5.25±0.26 mg eq AA/g DW, $F = 12.035$, $P = 0.002$). This study concludes that Deglet Nour date seeds are rich in bioactive compounds, efficiently extractable with minor differences among methods.

Keywords: Phoenix dactylifera L.; Scavenging effect; Polyphenols; Date seeds; Aqueous extract.

1. Introduction

Free radicals are highly reactive, unstable molecules that can significantly harm biological systems. These species induce considerable stress within biological cells, leading to various enzymatic processes that damage DNA. Such damage results in multiple lesions, which can ultimately cause mutations, loss of genetic information, and biochemical instability in the cellular environment. When the number of lesions is excessive, cells may undergo programmed cell death, known as apoptosis (Vassilis, 2018). This mechanism contributes to the phenomena of aging and the development of age-related disorders (Marzouk, 2021).

With increasing pollution, radiation, and poor hygiene, the body's need for antioxidants rises, making the supplementation of antioxidant-rich compounds necessary. Antioxidants not only scavenge free radicals but also enhance the efficacy of endogenous antioxidant enzymes. Medicinal plants serve as vital sources of therapy for numerous human diseases, as their extracts often possess potent antioxidant and anti-inflammatory properties (El Khasmi and Farh, 2022).

Among these plants, date seeds, particularly from the Deglet Nour variety, show significant therapeutic potential. This study aims to evaluate the antioxidant activity of various extracts of date seed powder in vitro, utilizing two distinct methodologies.

2. Materials and methods

2.1. Materials

2.1.1. Vegetal material

Dates are harvested in Algeria between September and October in the Biskra region. The seeds of fresh dates are cleaned and dried at room temperature away from light before being crushed and transformed into powder using an electric mill.

2.1.2. Preparation of date seeds extracts

Aqueous Extract (AE): To prepare the aqueous extract, 25g of date seed powder is infused in 250 mL of distilled water, brought to a boil for 10 minutes. The resulting extract is cooled to room temperature, filtered, and concentrated using rotary evaporation. The dry residue is collected and stored in the dark at a low temperature.

Hydro-Acetone Extract (HAE): The hydro-acetone extract of "Deglet Nour" date seed powder is prepared by mixing the powder with 80% acetone for at least 48 hours at room temperature. The extract is then filtered using filter paper, dried using a rotavapor type Büchi Rotavapor R-300, and the dry residue is stored in the dark at a low temperature.

Hydro-Alcoholic Extracts (Methanol and Ethanol) 80%: The date seed powder is separately macerated in two hydro-alcoholic solvents methanol (HME) and ethanol (HEE) each at 80% for 48 hours. After maceration, the extracts are filtered, dried, and stored in the dark at a low temperature.

2.2. Methods

2.2.1. Phytochemical screening

The qualitative examination of secondary metabolites is conducted using a standard phytochemical screening technique, following the method described by Sowmya et al. (2014). This technique involves testing plant extracts for the presence of key bioactive compounds such as alkaloids, flavonoids, phenolics, tannins, and saponins, using specific reagents and visual observations of color changes or precipitate formation, which indicate the presence of these phytochemicals.

2.2.2. Determination of total phenols (TPs)

The phenolic compounds of the extracts are measured using the Folin-Ciocalteu colorimetric technique described by Wong et al. (2006). This method is based on the reduction of Folin-Ciocalteu and phosphotungstic reagent compounds during the oxidation of phenols.

In test tubes, 2 mL of 2% sodium carbonate is added to 100 µL of each extract, which is either diluted to 1/100 and incubated for 5 minutes. Then, 100 µL of Folin-Ciocalteu reagent, diluted to 1/10, is added. The mixture is shaken and incubated for 30 minutes at room temperature, protected from light. The absorbance is measured at a wavelength of 750 nm using a Fluorescence Spectrophotometer (Model: SP-FL98). The polyphenol content in the extracts is expressed in milligrams of Gallic acid equivalents (GAE) per gram of dry weight. All tests are performed in triplicate for each sample.

2.2.3. Determination of total tannins (TTs)

The tannin content in the extracts is measured using the vanillin technique with hydrochloric acid, as described by Julkunen-Tiitto (1985).

The interaction of vanillin with the terminal flavonoid group of condensed tannins produces a complex with a red hue (anthocyanidols). The tannin content is proportional to the intensity of the apparent coloring measured against a blank with a spectrophotometer at 550nm.

A 50 µL of each extract are added to tubes holding 1.5 mL of the 4% vanillin/methanol solution and violently stirred. The concentrated hydrochloric acid is next added at a volume of 750 µL. The incubation period was 20 min at room temperature and light protection. For calibration curve, multiple concentrations of catechin ranging from 0 to 1000 µg/mL are generated from a stock solution. For each sample, the tests are run in triplicate.

2.2.4. Determination of total flavonoids (TFs)

The flavonoids in the extracts are quantified using the aluminum chloride (AlCl3) technique, with the latter reacting with the oxygen atoms on the carbon 4 and 5 of the flavonoids to produce a yellow coloring (Sammani et al., 2021).

After adding 150µL of 15% sodium nitrate (NaNO2) to 500µL of each extract with 2mL of H2O2, the mixture is incubated for 6 min at room temperature and shielded from light, followed by the addition of 150µL of 10% aluminum chloride (AlCl3, 6H2O) to each tube, followed by a second incubation. At 510 nm, the absorbance is measured against a blank.

Catechin is utilized as a calibration curve plotting standard, and its concentration is expressed in milligrams of catechin equivalent per gram of dry weight (mg CAE/g DW). For each sample, the tests were carried out in triplicate.

2.2.5. Assessment of Antioxidant Activity

2,2-diphenyl-1-picrylhydrazyl DPPH test:

The antioxidant capacity of the extracts is assessed in this test by evaluating the intensity of the color change after decolorization of the 2,2-diphenyl-1-picrylhydrazyl (DPPH) solution, which occurs due to the interaction between the DPPH radical and the free radical scavengers present in

the extracts. These results were compared to those of ascorbic acid, BHT, Trolox, and BHA using a slightly modified version of the technique described by Maisuthisakul et al. (2007).

The DPPH solution is made by dissolving 25 mg of DPPH powder in 100 mL of 99.8% methanol and storing it in the dark. Then, to 100 µL of extract at a predetermined concentration, 3.9 mL of DPPH solution is added, and the mixture is violently agitated for 10 seconds. The extracts and standards (ascorbic acid, Trolox, BHT, and BHA) are evaluated at concentrations ranging from 5 to 1000 µg/mL. At regular time intervals, the absorbance is measured at 505 nm against a methanol blank. For each concentration of the four extracts, three replications are carried out.

Ferric Reducing Antioxidant Power FRAP test:

The concept of the method described by AlevKaragözler et al. (2008) is the determination of the reducing activity in ferric iron (Fe3+) molecules extracts of the FRAP complex to ferrous iron (Fe2+), which results in a blue coloration.

One milliliter of each extract (from 0.007 to 2.5mg/mL) is combined with 2.5mL of 0.2M phosphate buffer (pH 6.6) and 2.5mL of 1% potassium ferricyanide K3[Fe (CN)6] solution. After 20 minutes of incubation at 50°C, the reaction is halted by adding 2.5mL of 10% trichloroacetic acid (TCA). For 10 minutes, the tubes are centrifuged at 3000 rpm. To 2.5mL of distilled water and 0.5mL of 0.1% aqueous FeCl3 (ferric chloride) solution, an aliquot (2.5mL) of supernatant is added. The absorbance of the reaction medium is measured at 700 nm in comparison to a blank produced under the identical circumstances but with distilled water instead of extract. The positive control is an antioxidant standard, ascorbic acid, Trolox, BHT, and BHA, whose absorbance was also measured. Increased absorbance corresponds to improved reduction capacities of date seed powder extracts. The following reaction is used to calculate the percentage of iron reduction capacity:

$$\text{Iron Reduction Capacity (\%)} = \left(\frac{A_0 - A_1}{A_0}\right) \times 100$$

A_0 symbolizes the absorbance of FeCl3 of the control; A_1 represents the absorbance of FeCl3 solution in the presence of the extract (Ghaisas et al., 2008).

Total Antioxidant Capacity TAC test:

The Total Antioxidant Capacity (TAC) of the extracts is determined using the molybdenum technique, which involves the reduction of molybdenum Mo (VI) $MoO4^{2-}$ in the extract to molybdenum Mo (V) MoO2+, resulting in a green [phosphate/Mo(V)] complex at acid pH.

A volum of 300µL of each extract is mixed with 3 mL of reagent solution (0.6 M sulfuric acid, 28 mM sodium phosphate and 4 mM ammonium molybdate). For the blank, 3 mL of reagent solution is mixed with 0.3 mL of methanol. The glass tubes containing the extracts and the blank are incubated at 95°C for 90 min. After cooling, the absorbance of the solutions is measured at 695 nm against a blank.

The total antioxidant capacity is expressed in milligram equivalents of ascorbic acid per gram of dry weight (mg AAE/ g DW). For each extract, the tests are carried out in triplicate (Prieto et al., 1999). The total antioxidant capacity is expressed in milligram equivalents of ascorbic acid per gram of dry weight (mg AAE/ g DW). For each extract, the tests are carried out in triplicate. The total antioxidant capacity is expressed in milligram equivalents of ascorbic acid per gram of dry weight (mg AAE/ g DW). For each extract, the tests are carried out in triplicate.

3. Results and discussions

3.1. Qualitative analysis

3.1.1. Phytochemical Screening

The phytochemical analysis of date seed powder using four different extract: AE, HME, HEE, and HAE revealed significant variations in the presence and concentration of bioactive compounds as shown in (Table 2). Saponins were most abundant in HEE, known for their antioxidant, anti-inflammatory, and anti-cancer properties. Quinones, important for antibacterial and anticancer activities, were present in AE and HME but absent in HEE and HAE. Tannins, recognized for their antioxidant, anti-inflammatory, and antimicrobial properties, were rich in AE, HME, and HEE, and abundant in HAE. Flavonoids, which possess antioxidant, anti-inflammatory, and anti-cancer properties, were most concentrated in HME. Polyphenols, crucial for their antioxidant and anti-inflammatory effects, were most abundant in HEE and HAE. Proteins, contributing to nutritional value, were only present in AE. Alkaloids, known for their pharmacological activities including analgesic, anti-inflammatory, and antimicrobial properties, were abundantly present in all extracts. These findings align with previous studies, such as those by Ranjitha Dhevi et al. (2017), which

found that tannins, saponins, and phenols were strongly present in similar screenings. The results indicate that different extraction methods significantly influence the phytochemical profile of date seed powder, with HEE and HAE, having high levels of polyphenols, being more suitable for antioxidant applications, while HME, rich in flavonoids, is preferable for anti-inflammatory purposes. AE, containing proteins, offers additional nutritional benefits. Overall, the diverse phytochemical composition underscores the potential of date seed powder as a source of natural bioactive compounds with various health benefits, warranting further studies to isolate these compounds and evaluate their specific biological activities (Ranjitha Dhevi et al., 2017).

Table 1 Qualitative Assessment of Phytochemical Compounds in Different Extracts

Compound	**AE**	**HME**	**HEE**	**HAE**
Saponins	++	+	+++	+
Quinones	++	+	-	-
Tannins	+++*	+++	+++	++
Flavonoids	++	+++	++	++
Polyphenols	++	++	+++	+++
Proteins	+			
Alkaloids	++	++	++	++

3.2. Quantitative analysis

3.1.2. Total Phenols (TPs)

The test of total phenols for four types of date seed extracts (HAE 80%, HEE 80%, HME 80%, and AE) at different concentrations (1000, 500, 250, and 125 mg), reveal significant variations depending on the concentration and type of extract used.

At the highest concentration (1000 mg), the HAE 80% extract exhibits the highest polyphenol content, reaching approximately 2.0 mg GAE/g dry weight (figure 1). The HEE 80% and HME 80% extracts show slightly lower values, while the AE extract displays the lowest content at this concentration. However, the differences between these extracts are not statistically significant ($P > 0.05$).

In contrast, at 500 mg, the HEE 80% extract shows a significant increase in polyphenol content, reaching around 1.8 mg GAE/g dry weight, with statistical significance ($P < 0.05$) compared to the other extracts. The other extracts (HAE 80%, HME 80%, and AE) display similar values around 1.6 mg GAE/g dry weight.

Moreover, at the 250 mg concentration, the polyphenol content decreases for all extracts. A significant difference is observed between some extracts ($P < 0.05$), with values ranging from approximately 1.3 to 1.5 mg GAE/g dry weight. The HAE 80% extract shows a slight superiority compared to the others.

At 125 mg, the polyphenol content further decreases. The AE extract shows a significant difference ($P < 0.01$), highlighting increased variability at this concentration. Furthermore, the other extracts (HAE 80%, HEE 80%, and HME 80%) display similar values around 1.0 to 1.2 mg GAE/g dry weight.

The error bars indicate variability in the data, with fluctuations generally less than 10% of the mean values. This variability could be attributed to differences in the stability and solubility of polyphenols or to experimental inconsistencies.

In the end, the HAE 80% extract proves to be the most effective for polyphenol extraction at the highest concentration (1000 mg). However, at lower concentrations, the extraction efficiency becomes more uniform among the extracts, although significant differences are observed at 500 mg for HEE 80% ($P < 0.05$) and at 125 mg for AE ($P < 0.01$). Thus, these results highlight the importance of extraction methods and solvents in determining the polyphenol content of date seeds and can guide future research aimed at optimizing these methods to maximize the yield of bioactive

compounds.

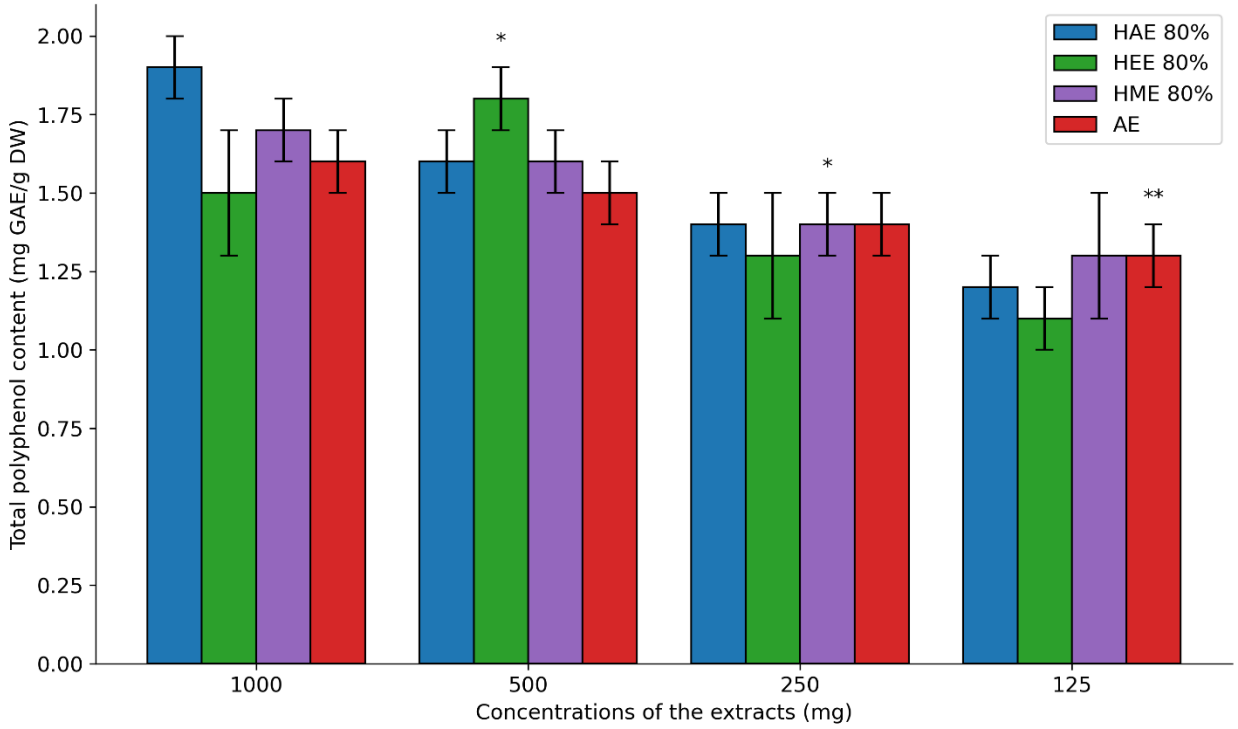

Figure 1: Total Polyphenol Content at Different Extract Concentrations

This chart shows the polyphenol content (mg GAE/g DW) for HAE 80%, HEE 80%, HME 80%, and AE extracts at various concentrations. A single asterisk (*) denotes significance at $P < 0.05$, while double asterisks (**) denote significance at $P < 0.01$.

3.1.3. Total Flavonoïds (TFs)

The flavonoid analysis reveals that the HAE 80% extract has the highest concentration with 216.11 ± 51.96 CAE/g DW. This is followed by the HEE 80% extract with 125.00 ± 94.9 mg CAE/g DW, and the HME 80% extract with 123.43 ± 92.43 mg CAE/g DW. In contrast, the AE extract shows the lowest concentration at 30.74 ± 6.05 mg CAE/g DW. This order is clearly illustrated in the chart (figure.2).

The error bars on the chart indicate the variability of the data, suggesting slight fluctuations in flavonoid content, typically less than 10% of the mean values. The ANOVA test highlights significant differences in flavonoid content between HAE 80% and AE ($p < 0.01$), indicating a substantial impact of the extraction method on flavonoid content.

Our results are consistent with previous studies (Afifi et al., 2017), which demonstrated that modifications in extraction conditions, such as temperature and solvent composition, can profoundly influence flavonoid yield. Specifically, reductions in extraction temperature and changes in ethanol ratios were shown to significantly decrease flavonoid content. This emphasizes the critical role of extraction parameters in determining the yield of bioactive compounds from plant materials.

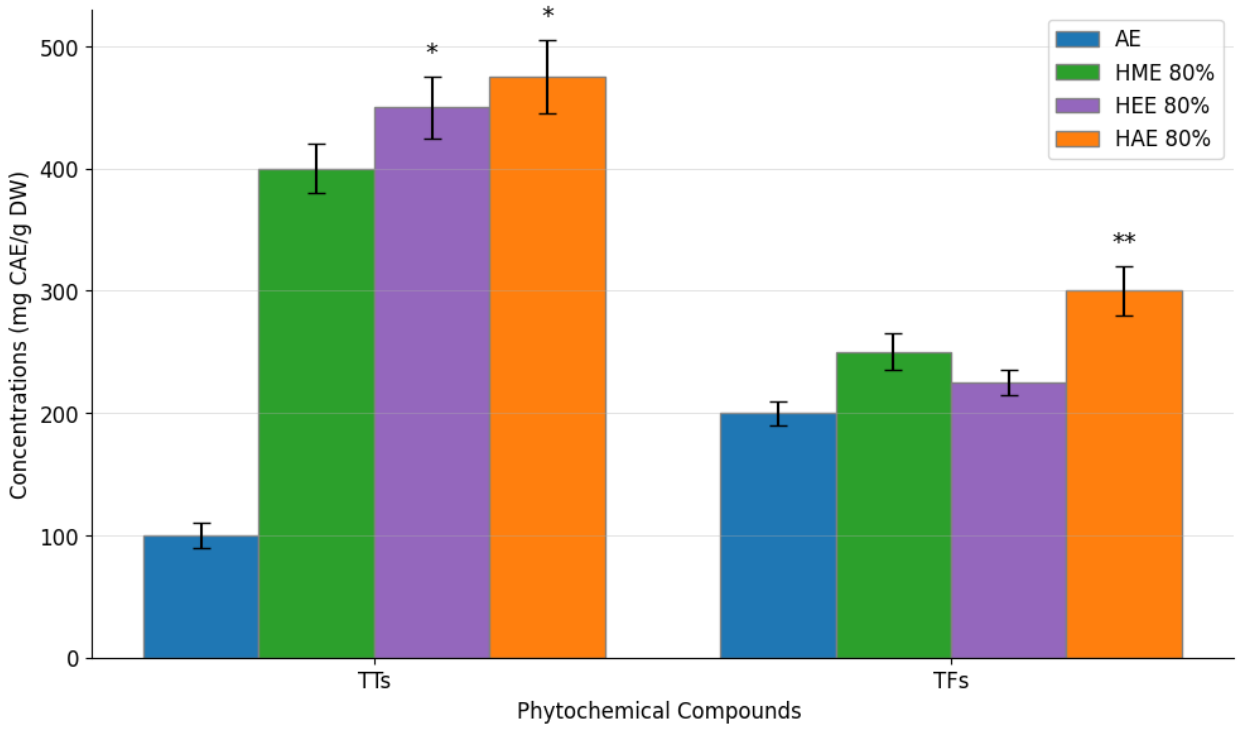

Figure 2: Total Flavonoid and Condensed Tannin Contents of the Four Extracts

The chart presents the concentrations of condensed tannins (TTs) and total flavonoids (TFs) in AE, HME 80%, HEE 80%, and HAE 80% extracts, expressed in mg CAE/g DW. A single asterisk (*) indicates a significant mean difference at $P < 0.05$, while double asterisks (**) indicate a significant mean difference at $P < 0.01$.

3.1.4. Total Tannins (TTs)

The varying concentrations of total tannins (TTs) in "Deglet Nour" date seeds extracted using different solvents may be attributed to several factors (figure. 2). The highest concentration observed with the hydroacetonic extract (HAE 80%) (472.22 ± 61.58 mg ECA/g DW) suggests

that its balanced hydrophilic and hydrophobic properties may have facilitated more efficient solubilization of tannin compounds compared to other solvents. The next highest concentration is found in the hydroethanolic extract (HEE 80%) at 450 ± 25 mg ECA/g DW, followed by the Hydromethanolic extract (HME 80%) at 411 ± 44,26 mg ECA/g DW, and finally the aqueous extract (AE) at 100 ± 10 mg ECA/g DW.

The differences in concentrations among the solvents could be due to their varying abilities to extract tannins under different extraction conditions, such as temperature and duration. The ANOVA-test indicated by asterisks on the TTs chart (figure 2), shows significant differences ($p < 0.05$) in tannin concentration between HEE 80%, AE and HAE 80%.

The lack of correlation between condensed tannins and overall polyphenol concentration suggests varietal differences in tannin composition within date seeds. This is further supported by the presence of catechins (31.3 ± 0.01 mg/g CE) and the absence of hydrolysable tannins. Lastly, the hardness of "Deglet Nour" date seeds, attributed to lignin accumulation from tannin molecules, highlights the complex interplay between biochemical composition and physical properties, impacting the extraction process and subsequent quantification of tannins (Bentrad and Rabea, 2020).

3.1.5. Antioxidant Activity

DPPH test:

The DPPH technique involves determining the percentage of reduction of the radical form DPPH in an antioxidant-containing solution to the non-radical form DPPH-H, which is accompanied by a change in the color of the solution from violet to yellow. The IC50 parameter is used to express our results. The IC50 is inversely related to the compound's antioxidant capacity (Table 1), hence the lower the IC50 value, the greater the antioxidant activity of the compound (Thouri et al., 2017).

Table 1. Classification of antioxidant power based on IC50 concentrations updated by Molyneux (2004)

IC50 Concentration	Classification
IC50 ≤ 50 µg/mL	Very strong
50 µg/mL < IC50 ≤ 100 µg/mL	Strong
100 µg/mL < IC50 ≤ 150 µg/mL	Moderate
150 µg/mL < IC50 ≤ 200 µg/mL	Weak

IC50 > 200 µg/mL	Very weak

Once the DPPH solution was added to the concentration series, the extract immediately and gradually changed from purple to yellow, signifying that the results were positive. The references tubes series also saw this similar color shift, including BHT, ascorbic acid, BHA, and Trolox.

Among the four extracts, the lowest IC50 value obtained is the HAE at the concentration of 2.6 ± 0.55 µg/ml, indicating that it has the greatest radical scavenging effect (Table 3), even though it is not statistically different from the other fractions. This result is quite near to Trolox 2.56 ± 0.57 µg/ml (Table 3), although AE suggests a poor inhibition 9.4±3.54 µg/ml of the DPPH radical, which may be explained by the difference solvent solubility and polarity and their extraction method (M'Hiri et al., 2015; Chaoui Boudghane et al., 2022).

Trolox, BHA, BHT, and ascorbic acid were utilized as references to compare the various activities. These last ones had 50% inhibition concentrations of 2.56±0.57; 1.37±0.52; 8.27± 10.55; and 1.37±0.52 (µg/ml) respectively differing against the DPPH radical.

FRAP test:

While the FRAP, TAC, and DPPH tests are all valuable methods for evaluating antioxidant capacity, each provides a unique perspective on the antioxidant characteristics of the samples. The choice of method depends on the specific type of antioxidant activity under investigation and the sample's properties (Munteanu and Apetrei 2021).

The FRAP (Ferric Reducing Antioxidant Power) technique was used to assess the antioxidant potential of date seed powder. The results revealed that the hydroalcoholic extract (HAE) exhibited a higher reduction capacity than other extracts, with a value of 10.14±2.23 µg/ml of DW (Table 3). The methanolic extract (HME) followed closely with a value of 12.84±2.68 µg/ml. In contrast, the ethanolic extract (HEE) and aqueous extract (AE) showed the lowest reduction capacities, with values of 18.39±11.84 µg/ml and 24.08±4.95 µg/ml, respectively.

These findings suggest that the date seed extracts, particularly from the "Deglet Nour" variety, have the ability to neutralize iron ions (Fe3+) effectively, which is indicative of their high phenolic content. Phenolic compounds, including polyphenols, flavonoids, and tannins, are known for their strong antioxidant properties (Warnasih et al., 2019), furthermore, some studies have discovered

a correlation between total phenols and antioxidant activity, reinforcing the significance of phenolic content in determining antioxidant potential.

TAC test:

Table 3 presents the average values for the neutralization of Mo (VI) molybdenum molecules into Mo (V) molybdenum, measured using the Total Antioxidant Capacity (TAC) technique. The TAC values indicate the antioxidant potential of different extracts of date seeds.

The aqueous extract (AE) of date seeds shows the lowest TAC value at 5.25 ± 0.26 mg AAE/g DW, with statistical significance ($F=12.035$, $P=0.002$) compared to other extracts. This suggests that the AE has the least antioxidant potential among the tested extracts.

In comparison, the hydroalcoholic extract (HAE) and ethanolic extract (HEE) exhibit higher TAC values of 12.22 ± 4.01 and 14.79 ± 1.90 mg AAE/g DW, respectively. These values indicate a moderate antioxidant capacity, which might be attributed to the presence of a higher concentration of antioxidant compounds.

The methanolic extract (HME) demonstrates the highest antioxidant capacity, with a TAC value of 15.25 ± 1.18 mg AAE/g DW. This superior antioxidant capacity suggests that HME is particularly rich in phenolic compounds, which are known for their strong antioxidant properties. Phenolic compounds are crucial for neutralizing free radicals and preventing oxidative stress, which is linked to various chronic diseases.

The findings highlight the potential use of date seed extracts, particularly the methanolic extract, as natural antioxidants in food and pharmaceutical industries. Further research could explore the specific phenolic compounds responsible for the high antioxidant activity in HME and evaluate their efficacy in practical applications.

3.1.6. Solvent-Dependent Antioxidant Activity in Date Seed Powder Extracts: A Comparison

The comparison of Date Seed Powder Extracts obtained using different solvents revealed significant variations in antioxidant activity, as supported by the ANOVA results ($p < 0.001$ for DPPH, FRAP, and TAC assays) (Table 3). In terms of DPPH radical scavenging activity (IC50

µg/ml), the hexane extract (HAE) exhibited the highest potency (2.63 ± 0.55 µg/ml), followed closely by hexane/methanol extract (HME) (3.09 ± 0.62 µg/ml), hydroalcoholic extract (HEE) (3.97 ± 3.77 µg/ml), and aqueous extract (AE) (9.42 ± 3.54 µg/ml).

Similarly, in the FRAP assay (IC50 µg/ml), HAE displayed the strongest ferric reducing antioxidant power (10.14 ± 2.23 µg/ml), followed by HME (12.84 ± 2.68 µg/ml), HEE (18.39 ± 11.84 µg/ml), and AE (24.08 ± 4.95 µg/ml).

Additionally, HME exhibited the highest Total Antioxidant Capacity (TAC) at 15.25 ± 1.18 mg AAE/g DW, followed by HEE (14.79 ± 1.90 mg AAE/g DW), HAE (12.22 ± 4.01 mg AAE/g DW), and AE (5.25 ± 0.26 mg AAE/g DW).

These findings suggest that HAE and HME extracts possess potent antioxidant properties, with HAE showing the strongest radical scavenging activity and HME exhibiting the highest total antioxidant capacity. Such variations in antioxidant activity could be attributed to differences in solvent extraction methods and the specific antioxidant compounds present in the extracts. The significant differences in antioxidant activities across the different extracts were confirmed by ANOVA tests ($p < 0.01$), indicating the robustness of the observed results (Table 3).

Table 3 Antioxidant Activity of Extracts and Standards as Determined by DPPH, FRAP Assays, and Total Antioxidant Capacity (TAC) in mg AAE/g DW.

Extracts and Standards	**DPPH (IC50) µg/ml**	**FRAP (IC50) µg/ml**	**TAC (mg AAE/g DW)**
AE	9.42 ± 3.54**	24.08 ± 4.95**	5.25 ± 0.26**
HME	3.09 ± 0.62**	12.84 ± 2.68**	15.25 ± 1.18**
HEE	3.97 ± 3.77	18.39 ± 11.84	14.79 ± 1.90
HAE	2.63 ± 0.55**	10.14 ± 2.23**	12.22 ± 4.01
Trolox	2.56 ± 0.57*	1.34 ± 0.017*	-
BHA	1.37 ± 0.52*	2.17 ± 0.066*	-
BHT	8.27 ± 10.55	22.37 ± 1.51	-
AA	1.37 ± 0.52*	1.51 ± 0.13*	-

4. Conclusions

The findings of this study indicate that extracts from the date seeds of the Deglet Nour variety demonstrate notable anti-radical activity, primarily attributed to their high concentrations of phenolic compounds such as tannins and flavonoids. This aligns with existing literature, including the work by Thouri et al. (2017), which supports the antioxidant potential of date seed extracts.

While these results are promising, it is essential to approach the implications with caution. Although the anti-radical properties suggest potential applications in the pharmaceutical, cosmetic, and food industries, further research is needed to fully understand the bioactive compounds' mechanisms, optimal extraction methods, and practical applications.

The value of these compounds in commercial settings should be contextualized within the broader landscape of natural product extraction and utilization. Therefore, while the potential for utilizing Deglet Nour date seeds in various industries is evident, additional studies are required to validate these applications and ensure their efficacy in real-world scenarios.

Acknowledgment

We would like to thank Ms. Tahir fatima zahra and Ms. Benoussar nesrine fatima zohra (PhD students affiliate in the same laboratory, laboratory of physiology and biochemistry of nutrition) for the assistance in calculation of data.

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