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Phytochemical Characterization and Biological Activities of the Hydroethanolic Extract of Algerian Deglet Nour Date Seeds (Phoenix dactylifera L.)

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ABSTRACT: Background and Objective: Date seeds, a by-product of the date fruit industry, are a valuable source of bioactive compounds and secondary metabolites. This study aims to valorize Deglet Nour date seeds (Phoenix dactylifera L.) by investigating their phytochemical composition and evaluating their antioxidant and antimicrobial activities.

Date seed powder was extracted using a hydroethanolic solvent mixture consisting of 70% ethanol and 30% distilled water (v/v). The phytochemical composition was evaluated by determining the total polyphenol, total flavonoid, and total tannin contents. Antioxidant activity was assessed using the DPPH radical-scavenging assay, expressed as the half-maximal inhibitory concentration (IC_{50}), and the ferric reducing antioxidant power (FRAP) assay. Antimicrobial activity was also investigated against the selected microbial strains.

The results show the highest content of total polyphenols (TPC), total flavonoids (TFC), and tannins were found in the extract, on the other hand, the highest antioxidant activities, scavenging 1,1-diphenyl-2-picrylhydrazyl radicals and reducing ferric ions were shown by the extract, on the other hand, the extract displayed inhibitory activity against both Gram-positive, Gram-negative bacteriaand antifungal activity against Candida albicans ATCC compared to the other extracts from the literature. The results thus obtained are in favor of possible exploitation of these seeds in food products thanks to their nutritional and chemical composition, as well as potential benefits to human health, and their role as a functional food.

This study aims to highlight the potential of Deglet Nour date seeds as a source of natural bioactive compounds and to explore their possible applications in the food and pharmaceutical industries.

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1. INTRODUCTION

In view of the side effects associated with conventional pharmaceutical treatments, there is growing interest in natural alternatives [1]. Certain plants, which are rich in bioactive compounds, have demonstrated antioxidant, anti-inflammatory, and antimicrobial activities [2].

Scientific research has increasingly focused on the extraction, identification, and quantification of these compounds from various sources, including agricultural and horticultural crops, as well as medicinal plants. In addition, agro-industrial by-products represent a valuable source of substances with a wide range of antioxidant and biological activities.

The date palm (*Phoenix dactylifera* L.), which has been cultivated for thousands of years in the arid regions of the Middle East and North Africa, represents a valuable source of nutrients and bioactive compounds. This plant, which is well adapted to extreme climatic conditions, is not only a source of energy-rich fruits but is also recognized for its medicinal potential due to the various constituents found in its fruits, seeds, and other part [3]. In Algeria, the Deglet Nour variety, renowned for its sweetness, translucent golden colour, and nutritional richness, occupies a central place in the Saharan oases (Gros-Balthazard et al., 2013) [4] . This variety is particularly valued for its content of polyphenols, flavonoids, and dietary fibre, making it a food of interest for its potential role in preventing metabolic diseases and reducing oxidative stress [5].

Date palm by-products include leaves, seeds, trunks, and fruit stalks, all of which have various applications. Among these by-products, date pits (DPs) are generated during several processing operations, including the production of pitted dates, date paste, date syrup, and date juice [6].

In many countries, date palm seeds (*Phoenix dactylifera* L.) are often discarded or partially incorporated into animal feed. They are also used as a raw material for the production of activated carbon [7,8]. However, their consumption by humans remains limited, mainly to infusions traditionally used to alleviate various infections [9,10].

The chemical composition of date palms (*Phoenix dactylifera* L.) and their seeds has been investigated in numerous studies, which have demonstrated that date seeds are rich in beneficial bioactive substances, including phenolic compounds, flavonoids, phenolic acids, and dietary fibre [11] .

These date palm by-products may therefore offer considerable added value and could represent a promising source of plant-based medicinal compounds [12] . A study published in the *Iranian Journal of Pharmaceutical Research* reported that date palm seeds extract exhibit significant antioxidant capacity, which is attributed to their high polyphenol content [13].

Recent pharmacological studies have revealed that date palm seeds are rich sources of functional nutritional components that may contribute to maintaining human health through various biological activities. These components may also help address nutritional deficiencies and combat infections and disorders associated with oxidative stress [14]. Furthermore, several studies have investigated the pharmacological benefits of date palm seeds, particularly their antiviral, antibacterial, antidiabetic, anti-inflammatory, and antioxidant properties [15] .

The aim of this study is to valorise date palm seeds (*Phoenix dactylifera* L.) from the Algerian Deglet Nour variety and investigate their potential benefits as a natural bioactive agent. To this end, date palm seeds powder was used to prepare an extract by maceration in a hydroethanolic solvent. The resulting extract was then investigated to determine its phytochemical composition and antioxidant capacity, with particular emphasis on evaluating its potential antibacterial and antifungal activities against selected microbial strains.

2. MATERIAL & METHODS

2.1. Plant material

The dates used in this research work are of the "Deglet Nour" variety were obtained from the Wilaya of Biskra, which is situated in the arid region of Southeastern Algeria; they were examined and analyzed in the laboratory. The seeds of these dates were first collected and then soaked in water for one hour. Next, they were cleaned and then dried at room temperature for 10–15 days. Finally, they were ground, using the laboratory crusher, and sieved [16] .

2.2. PREPARATION OF DATE SEEDS EXCTRACT

The extraction of bioactive compounds from raw date seed powder was carried out using the maceration method. A 10 g sample of date seed powder was immersed in 100 mL of a hydroethanolic solvent system (ethanol/water: 70/30, v/v). The extract was continuously stirred for 24 hours at room temperature in the dark to prevent the photodegradation of photosensitive compounds, following the protocols described by Al-Farsi et al. (2005) [17] and Thouri et al. (2011) [18] . After maceration, the extract was filtered through Whatman filter paper to remove cellular debris. The extract was then filtered using Whatman filter paper and concentrated using a rotary evaporator for four hours. They were finally dried in an oven at 55 °C, and kept at − 4 °C until use. The extract yield (R) was calculated using the formula:

$$R(\%) = (P / M) \times 100$$

Where **P** the weight of extract obtained and **M** is the total weight of vegetal material.

2.3. Determination of Total Polyphenols, Flavonoids and *condensed tannins*

Total polyphenol content (TPC) was determined using the Folin–Ciocalteu method according to Singleton et al. (1999) [19] and expressed as milligrams of gallic acid equivalents per gram of dry matter (mg GAE/g DW).

Total flavonoid content (TFC) was determined using the aluminum chloride method described by Zhishen et al. (1999) [20] and expressed as milligrams of catechin equivalents per gram of dry matter (mg CE/g DW).

The condensed tannins content (CTC) was determined using the vanillin method that was described by Julkunen-Titto. [21]. When proanthocianidins react with vanillin in an acidic medium, a red coloured complex is formed; this reaction occurs mainly with the free terminal flavan-3-ol units of the condensed tannins. The intensity of the colour obtained is proportional to the concentration of these units. Therefore, a volume of 50 µL from each sample was added to 1500 µL of the vanillin/methanol solution at 4%. Next, 750 µL of hydrochloric acid (HCl) were poured in the mixture which was then incubated for 20 minutes, at room temperature. Thereafter, the absorbance was measured at 550 nm. Finally, the standard catechin calibration curve, extending from 0 to 1000 µg/mL, was utilized in order to evaluate the CTC.

For both determinations, values were obtained from three measurements and expressed as mean ± standard deviation.

2.4. Antioxidant Activity

2.4.1.DPPH Assay (2,2-Diphenyl-1-picrylhydrazyl)

The antioxidant activity of the extract was evaluated based on the discoloration of the DPPH solution, resulting from the interaction between DPPH free radicals and the antioxidants present in the extracts. The results were compared with those obtained using ascorbic acid, butylated hydroxytoluene (BHT), Trolox, and butylated hydroxyanisole (BHA), according to a slightly modified method described by Sánchez-Moreno *et al.* [22].

The DPPH solution was prepared by dissolving 25 mg of DPPH powder in 100 mL of 99.8% methanol and was stored in the dark. Briefly, 3.9 mL of the DPPH solution was added to 100 µL of the extract at a specified concentration, and the mixture was vigorously shaken. The absorbance was measured at 505 nm against a methanol blank at extract concentrations ranging from 5 to 1000 µg/mL. All measurements were performed in triplicate.

2.4.2. FRAP Assay (Ferric Reducing Antioxidant Power)

The FRAP assay, described by Benzieet Strain, 1996[23] , was used to evaluate the reducing power of the extract based on the reduction of ferric iron (Fe^{3+}) to ferrous iron (Fe^{2+}), resulting in the development of a blue coloration. Briefly, 1 mL of the extract (0.007–2.5 mg/mL) was mixed with 2.5 mL of 0.2 M phosphate buffer (pH 6.6) and 2.5 mL of a 1% potassium ferricyanide solution ($K_3Fe(CN)_6$). After incubation at 50 °C for 20 minutes, the reaction was stopped by adding 2.5 mL of 10% trichloroacetic acid (TCA). An aliquot of 2.5 mL of the resulting supernatant was then mixed with 0.5 mL of a 0.1% aqueous $FeCl_3$ solution. The absorbance was measured at 700 nm. Higher absorbance values indicate greater reducing power.

2.5. Antimicrobial activity

2.5.1. Microorganisms

The antimicrobial activity of the hydroethanolic date seed extract was evaluated against microorganisms obtained from the American Type Culture Collection (ATCC). The tested microorganisms comprised two Gram-positive bacteria, *Staphylococcus*

aureus ATCC 25923 and *Bacillus cereus* ATCC 10876; three Gram-negative bacteria, *Pseudomonas aeruginosa* ATCC 27853, *Klebsiella pneumoniae* ATCC 700603, and *Escherichia coli* ATCC 25922; and one yeast, *Candida albicans* ATCC 10231.

2.5.2. Evaluation of antimicrobial activity using the agar well diffusion method

The antimicrobial activity of the hydroethanolic date seed extract was evaluated using the agar well diffusion method, following procedures adapted from the Clinical and Laboratory Standards Institute (CLSI) guidelines. Microbial suspensions were prepared from fresh cultures using sterile physiological saline (0.9% NaCl). Bacterial suspensions were adjusted to a turbidity equivalent to the 0.5 McFarland standard, while the *C.albicans* inoculum was prepared and standardized using an appropriate procedure for yeast susceptibility testing. Aliquots of 100 µL of each standardized microbial suspension were uniformly spread over the surface of Mueller Hinton agar (MHA) for bacterial strains and Sabouraud dextrose agar (SDA) for *C. albicans*. Wells measuring 6 mm in diameter were aseptically made in the agar using a sterile cork borer. Each agar well received 50 µL of the hydroethanolic date seed extract (100 mg/mL). Tobramycin and clotrimazole were used as positive controls for antibacterial and antifungal activity, respectively. The plates were maintained at room temperature for 1 h to allow diffusion and then incubated at 37 °C for 24 h for bacteria and 48 h for *C. albicans*. All experiments were performed in triplicate (n = 3) [24] . Antimicrobial activity was evaluated by measuring the total diameter of the inhibition zones.

2.5.3. Determination of the Minimum Inhibitory Concentration (MIC)

The antimicrobial activity of the seed extract was evaluated by determining the minimum inhibitory concentration (MIC), defined as the lowest concentration of the extract capable of inhibiting at least 90% of microbial growth [25]. The assay was performed using the broth microdilution technique, following the procedure described by Sharma et al. (2020), with appropriate modifications.The seed extract was dissolved in 10% dimethyl sulfoxide (DMSO) to prepare the stock solution. Two-fold serial dilutions were prepared in sterile 96-well microplates using MuellerHinton broth (MHB) for bacterial strains and Sabouraud dextrose broth (SDB) for yeast. The tested concentrations ranged from 100 to 0.19 mg/mL. Each well contained 100 µL of the corresponding extract dilution, 10 µL of microbial inoculum (10^6 CFU/mL for bacteria and 10^7 CFU/mL for *Candida albicans*), and 90 µL of the appropriate culture medium, giving a final volume of 200 µL per well. Wells containing the microbial inoculum and culture medium without the seed extract served as positive growth controls, whereas wells containing culture medium alone served as negative controls. A solvent control containing the corresponding concentration of DMSO was also necessary to assess any inhibitory effect attributable to the solvent itself.

The microplates were incubated at 37°C for 24 h for bacteria and 48 h for yeast. Subsequently, 40 µL of triphenyl tetrazolium chloride (TTC; 0.4 mg/mL) was added to each well, and the plates were incubated for an additional 30 min at 37°C. The development of a pink coloration indicated microbial metabolic activity, whereas the absence of color development suggested inhibition of growth. The MIC was recorded as the lowest concentration of the seed extract that prevented detectable microbial growth under the experimental conditions.

2.5.4. Determination of the Minimum Bactericidal Concentration (MBC) and Minimum Fungicidal Concentration (MFC)

The minimum bactericidal concentration (MBC) and minimum fungicidal concentration (MFC) were determined to evaluate the lethal effects of the seed extract against bacterial and fungal strains, respectively. These parameters were defined as the lowest concentrations producing a 99.9% reduction in the initial microbial population [26, 27]. Aliquots of 10 µL were collected from wells showing no visible growth during the MIC assay and transferred onto Mueller Hinton agar for bacteria and Sabouraud agar for yeast. The plates were incubated at 37°C for 24 h for bacterial strains and 48 h for yeast. Following incubation, microbial colony formation was examined to determine the lowest concentration associated with a bactericidal or fungicidal effect. The antimicrobial activity was characterized using the MBC/MIC ratio for bacteria and the MFC/MIC ratio for yeast. According to the criteria described by Sbayou et al (2014) [28] , ratios ≤ 4 indicated bactericidal or fungicidal activity, whereas ratios > 4 suggested bacteriostatic or fungistatic activity, respectively.

Statistical analysis

Experimental results are reported as mean ± standard deviation (SD). Differences between groups were examined by one-way ANOVA, followed by Tukey's multiple-comparison procedure. Statistical significance was defined as : ***P< 0.001, **P< 0.01, *P< 0.05

3. RESULTS

3.1. Determination of the Extraction Yield of Date Seed Powder

According to our results, the extraction yield was **14.5%**, indicating the effectiveness of the solvent system used, namely the **hydroethanolic mixture (30:70, v/v)**.

Table 1: *Yields of* hydroethanolic extract date seeds (HEEDS)

Extract	Gross mass (g)	Dry extract mass (g)	Yields (%)
HEEDS	10	1,45	14,5

3.2. Determination of Phytochemical Composition

The phytochemical analysis (Figure 1) of date seed (DS) powder using a hydroethanolic extract revealed quantitative variations in the major secondary metabolites, with flavonoids being the most abundant compounds compared with total phenolics and tannins. This higher extraction efficiency may be attributed to the enhanced solubilization of phenolic compounds in the semi-polar solvent system, which promotes their diffusion from the plant matrix.

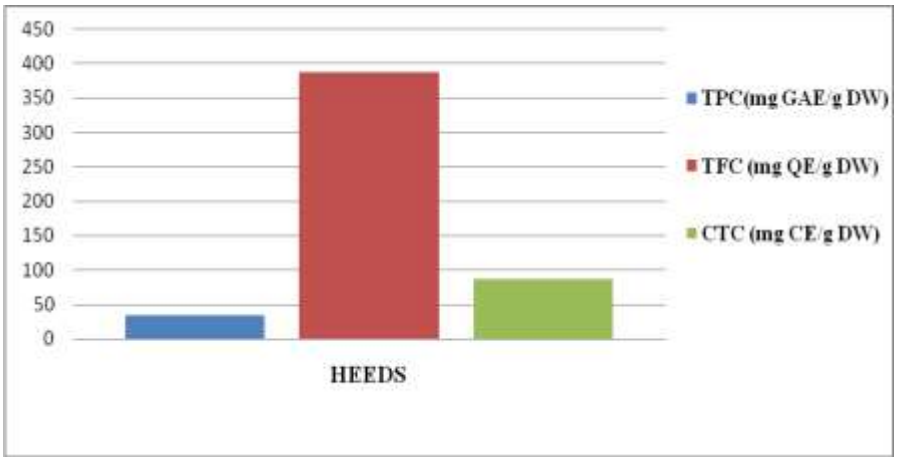


Figure 1: Total Phenolic, Flavonoid, and Tannin Contents of the Hydroethanolic Extract of Date Seeds. TPC: Total Phenolics Content. TFC: Total Flavonoids Content. CTC: Condensed tannins content. GAE: Gallic Acid Equivalent. QE: quercetin Equivalent. CE: Catechin Equivalent. DW: Dried Weight. HEEDS: hydroethanolic extract date seeds

3.3. Determination of Antioxidant Activity

3.3.1. DPPH Assay

The DPPH method evaluates the antioxidant capacity of extracts by measuring the reduction of the DPPH free radical to its stable form (DPPH-H), accompanied by a color change from violet to yellow. Antioxidant activity is quantified by the IC_{50} value, which is inversely proportional to antioxidant capacity: the lower the IC_{50} value, the higher the antioxidant activity .

Following the addition of DPPH, a progressive color change was observed in all extracts, indicating measurable antioxidant activity. The reference standards (BHT, ascorbic acid, BHA, and Trolox) exhibited a similar colorimetric response.

These results demonstrate that the HEEDS extract exhibits remarkable antioxidant activity, comparable to that of the reference antioxidants, suggesting a high content of antioxidant flavonoids compounds and phenolic

3.3.2. FRAP Assay

The FRAP (Ferric Reducing Antioxidant Power) assay measures the ability of an extract to reduce ferric ions (Fe^{3+}) to ferrous ions (Fe^{2+}), there by reflecting its overall reducing capacity and antioxidant potential. The results obtained (Table 2) indicate that the HEEDS extract exhibited the highest reducing capacity, with a mean value of 17.25 ± 0.24 µg/mL of dry matter.

These findings suggest that the extract obtained using the organic solvent mixture exhibits a greater ability to reduce ferric ions, which may be associated with a high content of phenolic compounds and flavonoids contributing to its antioxidant activity.

Table 2: Antioxidant Activities (DPPH and FRAP) of the Extract and Standard Compounds

tExtract / Standards	DPPH (IC50, µg/mL)	FRAP (IC50, µg/mL)
HEEDS	3,51 ± 0,03	17,25±0,24
Trolox	2,44 ± 0,46	1,24 ± 0,017
BHA	1,37 ± 0,52	2,17 ± 0,066
BHT	8,27 ± 10,55	22,37 ± 1,51
AA (Ascorbic Acid)	1,37 ± 0,52	1,51 ± 0,13

Antimicrobial activity of the extract

The in-vitro antimicrobial activity of the extract was evaluated against five bacterial strains and one fungal strain using the agar diffusion method, with tobramycin and clotrimazole serving as reference antimicrobial agents. As presented in Table 3 , the extract exhibited the highest antibacterial activity against *Escherichia coli* ATCC 25922, with an inhibition zone diameter (IZD) of 14.66 ± 0.44 mm, followed by *Bacillus cereus* ATCC 10876 (13.33 ± 0.44 mm), *Staphylococcus aureus* ATCC 25923 (11.66 ± 1.11 mm), *Klebsiella pneumoniae* ATCC 700603 (11.16 ± 0.77 mm), and *Pseudomonas aeruginosa* ATCC 27853 (10.83 ± 0.77 mm). These results indicate that the extract displayed inhibitory activity against both Gram-positive and Gram-negative bacteria, with inhibition zones falling within the 10 -20 mm range, classified as fair activity according to the cited criteria[29] . Furthermore, the extract showed antifungal activity against *Candida albicans* ATCC 10231, with an inhibition zone of 12.83 ± 1.44 mm. These findings highlight the potential of the extract as a source of bioactive compounds with antibacterial and antifungal properties.

Table 3. Antimicrobial activity of date seed extract and standard drug

Microorganisms	Inhibition diameter (mm)		
	Extract	Tobramycin	Clotrimazole
S.aureus ATCC 25923	11.66 ± 1.11	18.58 ± 0.38**	_
B. cereus ATCC 10876	13.33 ± 0.44	15.49 ± 0.25**	_
P.aeruginosa ATCC 27853	10.83 ± 0.77	20.34 ± 0.53***	_
*K.pneumoniae*ATCC700603	11.16 ± 0.77	0.00 ± 0.00	_
E.coli ATCC 25922	14.66 ± 0.44	20.12 ± 0.70**	_
C.albicans ATCC 10231	12.83 1.44	_	19.80± 0.20**

Data are represented as mean ± standard deviation of three experiments. Statistical differences compared to the date seed extract are indicated as: ***P< 0.001, ** P< 0.01.

The MIC and MBC/MFC results are summarized in Table 4. *B. cereus* ATCC 10876 exhibited the highest susceptibility, with the lowest MIC (6.25 mg/mL). Based on the MBC/MIC ratios, the extract showed bactericidal activity against *S. aureus*, *B. cereus*, *Klebsiella pneumoniae*, and *Escherichia coli*, with ratios ranging from 1 to 2. In contrast, *P. aeruginosa* ATCC 27853 displayed an MBC of 100 mg/mL and an MBC/MIC ratio of 8.16, indicating a predominantly bacteriostatic effect according to the commonly used classification. For *C. albicans* ATCC 10231, the MIC and MFC were 12.5 and 25 mg/mL, respectively, resulting in an MFC/MIC ratio of 2, consistent with fungicidal activity. These findings demonstrate that the extract's antimicrobial effects vary depending on the microorganism tested.

Table 4. MIC, MBC/MFC and antimicrobial activity of seed extract.

Microorganisms	MIC	MBC/MFC	Ratio	Activity
S.aureus ATCC 25923	12.5	12.5	1	Bactericidal
B. cereus ATCC 10876	6.25	12.5	2	Bactericidal
P.aeruginosa ATCC 27853	12.5	100	8.16	Bacteriostatic
*K.pneumoniae*ATCC700603	12.5	25	2	Bactericidal
E.coli ATCC 25922	12.5	12.5	1	Bactericidal
C.albicans ATCC 10231	12.5	25	2	Fungicidal

Statistical analysis

Experimental results are reported as mean ± standard deviation (SD). Differences between groups were examined by one-way ANOVA, followed by Tukey's multiple-comparison procedure. Statistical significance was defined as : ***P< 0.001, **P< 0.01, *P< 0.05

4. DISCUSSION

The present study was designed to explore the potential nutritional and valorization applications of date industry waste. Herbal medicine is an ancient practice in traditional medicine, and certain medicinal plants are particularly recognized for their anti-inflammatory effects, which are often associated with their content of secondary metabolites.

The aim of this study was to investigate the antibacterial and antifungal activities of date seed extracts against microbial strains. To achieve this objective, phytochemical characterization was essential for identifying the secondary metabolites and bioactive compounds present in date seeds (DS). The choice of extraction solvent plays a crucial role in the recovery of secondary metabolites from plant matrices.

The hydroethanolic extract (HEE), which was rich in flavonoids, exhibited considerable antioxidant potential. These compounds are widely recognized for their ability to scavenge free radicals and mitigate oxidative stress, thereby helping to protect cells against oxidative damage. Flavonoids are also associated with anti-inflammatory and vasculoprotective properties, which are characteristic of this class of secondary metabolites.

Overall, the simultaneous presence of tannins, flavonoids, and other phenolic compounds may contribute to the pharmacological potential of date seeds, positioning them as a promising natural source of bioactive compounds for applications in the nutraceutical, cosmetic, and pharmaceutical industries.

The 70% hydroethanolic extract (HEE), characterized by its high flavonoid content, highlights the effectiveness of hydroethanolic solvent systems for extracting these compounds. This effectiveness may be attributed to their ability to solubilize compounds with different polarities, including highly polar and moderately non-polar constituents. These findings are consistent with those reported by Bouabdelah et al. (2025) [30] **.**

Conversely, the lower levels of total phenolics and tannins may be explained by incomplete solubilization of certain phenolic compounds or by oxidative instability under specific extraction conditions, potentially resulting in the partial degradation of these constituents. However, these explanations require further experimental investigation.

In this study, three complementary in vitro assays—DPPH, FRAP, and TAC—were used to evaluate the antioxidant activity of date seed extracts through different mechanisms. Regarding the DPPH assay, the results indicate that the polarity of the extraction solvent strongly influences the antioxidant activity of the extracts. This observation is consistent with the findings of Thouri et al. (2017) [31] . The results of the FRAP assay further confirm that the reducing capacity of date seed extracts depends strongly on the extraction solvent. According to Munteanu and Apetrei (2021) [32] , the FRAP assay specifically evaluates the reducing capacity of antioxidants, which is associated with the electron-donating properties of antioxidant molecules, including phenolic compounds. The findings suggest that date seeds contain phenolic constituents capable of donating electrons and reducing ferric ions (Fe^{3+}) to ferrous ions (Fe^{2+}).

These observations are also supported by Warnasih et al. (2019) [33] , who reported a positive relationship between total phenolic content and antioxidant activity in different plant extracts.

Overall, these findings highlight the potential of hydroacetonic and hydromethanolic extracts of 'Deglet Nour' date seeds as promising sources of natural antioxidants. Such extracts may have potential applications in the food, pharmaceutical, and cosmetic industries as possible alternatives to synthetic antioxidants, such as butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT). However, further toxicological and safety assessments are required before drawing conclusions regarding their suitability as substitutes for synthetic antioxidants.

The hydroethanolic seed extract of *Phoenix dactylifera* L. exhibited antibacterial and antifungal activity against the microorganisms investigated. Previous studies have reported biological activities in date seed extracts, including those obtained from the Algerian cultivar 'Deglet Nour' **(**[34,35 and 35]**.** These effects may be associated with secondary metabolites, particularly phenolic compounds, tannins, and flavonoids, which have been investigated for their antimicrobial properties [37,38] **.** However, the contribution of individual compounds to the observed activity remains to be established through detailed phytochemical characterization.

The antibacterial activity of the extract varied among the tested strains, with inhibition zones ranging from 10.83 ± 0.77 to 14.66 ± 0.44 mm and minimum inhibitory concentration (MIC) values ranging from 6.25 to 12.50 mg/mL. *Escherichia coli* ATCC 25922 exhibited the largest inhibition zone (14.66 ± 0.44 mm), whereas *Bacillus cereus* ATCC 10876 showed the lowest MIC (6.25 mg/mL), indicating that bacterial growth was inhibited at a lower extract concentration. According to the criteria applied in this study, the minimum bactericidal concentration (MBC)/MIC ratios of 1 for *E. coli* and 2 for *B. cereus* are consistent with bactericidal activity. These findings demonstrate differences in susceptibility among the tested bacterial strains. Comparisons with previous studies on date seed extracts should take into account variations in extraction procedures, chemical composition, and antimicrobial testing conditions [39,40]**.** The activity observed against *Klebsiella pneumoniae* ATCC 700603 is also noteworthy. The extract produced an inhibition zone of 11.16 ± 0.77 mm, with an MIC of 12.50 mg/mL and an MBC of 25 mg/mL, corresponding to an MBC/MIC ratio of 2. This ratio is consistent with bactericidal activity under the criteria applied. In contrast, no inhibition zone was observed with tobramycin under the experimental conditions employed. In contrast, *Pseudomonas aeruginosa* ATCC 27853 exhibited an MBC of 100 mg/mL and an MBC/MIC ratio of 8.16, suggesting a predominantly bacteriostatic effect according to the criteria applied. The higher concentration required to achieve bacterial killing may reflect differences in susceptibility among the tested microorganisms. The low permeability of the outer membrane and the activity of multidrug efflux systems are recognized contributors to the reduced susceptibility of *P. aeruginosa* to various antimicrobial agents [41].

The hydroethanolic extract also exhibited antifungal activity against *Candida albicans* ATCC 10231, with an inhibition zone of 12.83 ± 1.44 mm, an MIC of 12.50 mg/mL, and a minimum fungicidal concentration (MFC) of 25 mg/mL. The resulting MFC/MIC ratio of 2 is consistent with fungicidal activity according to the criteria applied. This finding is in line with previous investigations reporting antifungal properties in date seed extracts[42,43] **.**

CONCLUSION

The quantitative and qualitative evaluation of Algerian Deglet Nour date seed powder (Phoenix dactylifera L.), based on the results obtained in this study, demonstrates its richness in bioactive compounds, particularly polyphenols, flavonoids, and tannins. These compounds contribute to the antioxidant potential of date seeds, enabling them to scavenge free radicals and, consequently, potentially prevent metabolic disorders caused by oxidative stress.

In addition to these properties, date seeds also exhibit bacteriostatic, bactericidal, and fungicidal effects against the microbial strains tested.

Therefore, it can be concluded that date seed powder should be valorized in various fields, particularly in nutrition, as a natural dietary supplement. It may also represent a potential source of bioactive compounds for the development of therapeutic alternatives.

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Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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