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Evaluation of antifungal activity and Chemical Composition of the Phoenix dactylifera L. heart in southeast of Algeria

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Abstract

This study aimed to investigate the chemical composition and in vitro antifungal properties of hydroethanolic extracts derived from heart of data palm (Phoenix dactylifera.L). Specifically, it examined extracts from the heart palm of the Ouargla region (HPO) and the El M'Ghair region (HPM) for their effectiveness against phytopathogenic fungi isolated from post-harvest potato tubers, namely Fusarium proliferatum and Wickerhamomyces anomalus. Phytochemical analysis revealed the presence of phenols, flavonoids, tannins, and saponins, with total phenolic compounds content ranging from 12.08 to 16.02 (mg GAE/g DW) and total flavonoid content between 6.47 and 11.36 (mg QE/g DW). Analysis by UPLC-ESI-MS/MS excessive percentages of extract's (HPO and HPM) identified ferulic acid , epicatechin, catechin, coumaric acids, salicylic acid. Antifungal activity, assessed using the direct contact method, revealed that both extracts exhibited potent efficacy, achieving complete inhibition (100%) of the tested fungal strains at concentrations of 16% and 20 %. These findings highlight the promising antifungal potential of these extracts against common phytopathogens that affect post-harvest potato tubers.

Keywords: Heart Phoenix dactylifera, chemical composition, Phenolics compounds, flavonoid, antifungal activity, Phytochemical.

1. Introduction

The date palm *(Phoenix dactylifera L.)* is among the oldest cultivated crops in the Old World, having been widely grown in the Middle East and North Africa for over 5,000 years due to its exceptional nutritional and medicinal value. Today, it continues to be regarded as one of the most strategically important agricultural crops in arid and semi-arid environments [1] [2].

The benefits of the date palm are not limited to the dates it produces; the date palm also provides secondary products from its other parts, which some may consider waste but represent an economic commodity that can be used as a source for many local industries, especially in areas where date palm cultivation prevails. It is an important source for many medicinal industries (date honey, pollen, natural oils, etc). These products include trunks, fronds, fibers, coir, and low-quality dates and seeds, including the heart of the palm, known as "the heart of the palm," which is the central part that refers to the trunk cells of the palm tree and is extracted from the buds that grow from the top of the palm or the main branch covered with broad leaves. It is usually obtained from young trees that are between 4 to 5 years old. This edible part is commonly consumed as fresh vegetables in areas where palm trees are cultivated [1] [3] [4].

Research indicates that the heart of the palm abundant in numerous active compounds that have biologically effective properties, the amount of these compounds varies according to the type of palm, the environment, and the cultivation conditions [5] [6].

Upon review of the literature, only a few investigations are available on the chemical composition of the date palm heart, particularly within the Algerian context. Although Algeria is one of the largest global producers of date palms, this specific

plant component has received little to no scientific attention locally. Therefore, This study represents the first scientific attempt to determine the chemical composition and highlight the antifungal activity of the active compounds extracted of the date palm heart *(Phoenix dactylifera L.)* grown in Algeria, to provide new insights into its nutritional and phytochemical properties, and to help expand the currently limited national scientific data available on this specific part of the plant.

Materials and methods

Fungal Strains:

This study focused on two fungal species, *Fusarium proliferatum* and *Wickerhamomyces anomalus*, which were isolated from post-harvest potato tubers from the El Oued region ((N31°57'47" E5°20'31" southeastern Algeria).The plant pathogenic strains under investigation underwent purification processes and were identified using the Polymerase Chain Reaction (PCR) technique. These strains have been assigned the following deposition numbers in the GenBank database, part of the National Center for Biotechnology Information (NCBI): OQ606246.1 and OQ771178.1. The PDA culture medium (Potato Dextrose Agar) was used as it is often advised for finding and quantifying molds, in addition to its use in preserving isolated strains following their sub-culturing[7].

Sampling:

The heart of date palm (*Phoenix dactylifera L*, var., male) was collected from Ouargla region (southeast of Algeria) (5º18′18″E 31º56′27″N) in the month of February 2024. And from El M'Ghair region, southeast of Algeria (6º00′19.6″E 33º31′12.4″N) in April 2023.

After that, Samples of Al-Goumar (Palm heart) were washed well to remove debris and dust, then dried using a freeze-drying device. The samples were ground into a powder and stored in airtight glass bottles, away from light and moisture.

Preparation of the extract

10 g of material powder and 100 mL of (70%) hydroethanolic are introduced into an Erlenmeyer flask. The whole is macerated for 24 h at room temperature. The extract was filtered through Whatman No.1 filter paper and the filtrate was collected; then the ethanol of the crude extract was removed using a rotary evaporator. Finally, the obtained extract was kept in the dark at +4°C until further analysis.

Phytochemical Screening:

Approved standard methods as given below (**table 1**) are used to perform a qualitative analysis in the plant extract of heart of *Phoenix dactylifera* and detect phytochemical compounds like phenols, flavonoids, alkaloids, tannins , saponins, glycosides, Coumarins, terpenes and steroids.

Table 1:Type of phytochemical screening

Phytochemical test	The test's name	Observations indicating of presence	References
phenols	Ferric chloride test	Dark blue /bluish black colour	[9][8]
flavonoids	Shinod's test	Deep pink colour	[12] [11] [10]
alkaloids	Mayer's test	A yellowish or creamy white precipitate	[13] [9]
tannins	Braymer's test	A bluish-green color	[16] [15] [14]
saponins	Foam test	Formation of 3 cm thick foam stable	[17] [12]
glycosides	Fehling's test	A red precipitate	[18] [16]
Coumarins	NaOH test	A yellow colour	[20] [19] [17]
terpenes	Salkowski test	reddish brown or deep red precipitate	[16] [12] [11]
steroids			

LC-MS Chromatography analysis :

The qualitative analysis of phenolic compounds in the extracts of palm heart was performed using the UPLC-ESI-MS/MS, which combines ultra-high-performance liquid chromatography (LC) with electrospray ionization tandem mass spectrometry (MS) under the conditions listed in (**Table 2**).

Table 2: Conditions for Liquid Chromatography (LC) Coupled with Mass Spectrometry (MS)

Processed by	UPLC-ESI-MS-MS Shimadzu 8040
Mobile phase	solvent water, 0.1% formic acid, and solvent B methanol
Volume injection	5 µL
Flow rate	0.2 mL/min
Column	Restek Ultra C18 3µm 150x4.6mm
The gradient	0 min to 0.2min A 98 % 0.2 min to. 2.5min A 25% 2.5 min to 4 min A 0% 4 min to 10min A 0% 10min to 10.01 min A 98% 10.1 min to 15min A 98%
The electrospray ionization (ESI) conditions	
CID gas	230 KPs
conversion dynode	−6.00 Kv◦C
DL temperature	250 ◦C
nebulizing gas flow	3.00 L/min
heat block	400 ◦C
drying gas flow	10L/min

Quantitative Analysis:

Total Phenol Contents Determination

Total phenolic compounds were determined by the Folin-Ciocalteu colorimetric method [21]. Sample (100 µL) was added to 150 µL volume of Folin-Ciocalteu reagent (diluted 1:10, v/v in distilled water). After 5 min, 50 µL of Na2CO3 (6% w/v) was added to the mixture. The absorbance was measured at 725 nm using a a UV-Vis spectrophotometer for 90 min at room temperature. Calibration curves were constructed using standard solutions of gallic acid, and results were expressed as mg of gallic acid equivalents per gram (mg GAE / g DW) of dry weight heart of the palm.

Total Flavonoid contents Determination

The content was quantified using the aluminum chloride colorimetric method[22]. Briefly, 150 µL of the sample were mixed with 150 µL of 5% Na2NO2, followed by the addition of 300 µL of 10% AlCl3, and the sample was incubated at room temperature for 5 min. Then, 100 µL of NaOH 2 mol/L were added, and the solution was homogenized. The absorbance was read at 510 nm. Total flavonoid content was calculated with a calibration curve of quercetin, and the results were expressed as mg of quercetin equivalents per gram (mg GAE / g DW) of dry weight heart of the palm.

Antifungal Test

Method:

The antifungal activity of phenolic extracts was studied using the direct contact technique according to the method described by (Mohammedi et al. 2012) [23], with some slight modifications. PDA (Potato Dextrose Agar) culture medium was prepared and the extract was added to it at different concentrations while it was still in a liquid state at a temperature of 56 °C. The mixture was then stirred for two minutes to ensure homogeneous distribution of the extract, and then poured into Petri dishes with a diameter of 50 mm. Once the medium solidified, inoculation was carried out by placing a 5 mm fungal disc, sourced from a 7-day-old active fungal culture, in the center of each dish under sterile conditions. Control plates containing only the PDA medium without any extract were also prepared to serve as reference samples. The dishes were incubated at a constant temperature of 25 ± 2°C. Each treatment was performed in triplicates, and the radial growth of the fungi was measured daily over a period of ten days.

The fungal growth (expressed in mm) was assessed after the incubation period, which lasted for ten days (240 hours). This was done by measuring the average of three perpendicular diameters passing through the center of the fungal disc. The results were consistently compared with the control dishes to determine the effectiveness of the extracts in inhibiting or decrease fungal expansion.

Antifungal Index :

The reduction in fungal diameter growth was measured compared to the control and the percentage fungal inhibition was calculated using the formulae [24] :

$$\mathbf{I(\%) = [(D_c - D_t / D_c)] \times 100}$$

where: $\mathbf{D_{test}}$ and $\mathbf{D_{control}}$ represent the fungal diameter growth when the extracted samples are present and without the presence of extracted, respectively.

Statistical analysis:

The results were presented as the mean values ± SD. The difference between the values as analyzed by one-way analysis of variance (ANOVA) were calculated from the obtained results for each parameter using XLSTAT software (2019).

Results and discussion

Phytochemical Tests:

Phytochemical tests include the detection of various categories of secondary metabolites present in the studied part of the plant through qualitative reactions for differentiation. These reactions depend on precipitation or coloration phenomena using specific chemicals or reagents for each family of compounds. The results of the phytochemical tests conducted on the extract of the heart of the date palm)HPO and HPM) are compiled in (Table 3). We observed that phytochemical analysis identified that heart palm extracts contain a variety of bioactive secondary metabolites, such as phenols, flavonoids, tannins, coumarins, glycosides, saponins, terpenes, and the absence of alkaloids. These compounds are widely known for their important role in antioxidant defense mechanisms and antimicrobial properties in plants. Phenolic compounds and flavonoids are particularly crucial in plant defenses against fungal and bacterial pathogens, as they enhance resistance to oxidative stress and inhibit microbial growth [25] [26]. Likewise, tannins are associated with inhibiting the spread of pathogens and regulating inflammatory responses [27]. Terpenes, known for their diverse functions, help alleviate abiotic stress while also exhibiting direct antimicrobial activity [28]. Glycosides and saponins further strengthen plant protection, have a protective function in the plant against insects[29][30]. In addition, specific phenolic subgroups such as coumarin affect oxidative balance and exhibit direct antimicrobial effects, further enhancing plant resilience[30][31].

Table 3: Phytochemical screening of The heart of (*Phoenix dactylifera L)*

Phytochemical test	Extract of HPO	Extract of HPM
phenols	+	+
flavonoids	+	+
alkaloids	-	-
tannins	+	+
saponins	+	+
glycosides	+	+
Coumarins	+	+
terpenes	+	+

LC-MS Chromatography analysis :

High-precision characterization of bioactive secondary metabolites in date palm heart extract was achieved using ultra-high performance liquid chromatography-electrospray ionization tandem mass spectrometry (UPLC-ESI-MS/MS). Semi-quantitative analysis based on chromatographic peak areas enabled accurate comparison of the relative abundance of major compounds in each extract (**Table 3**). A total of Twenty-seven bioactive compounds were identified in extracts (HPO and HPM), mainly classified into phenolic acids and flavonoids. The detected phenolic acids included sinapic acid, kojic acid, ferulic acid, caffeic acid, gallic acid, vanillic acid, p-coumaric acid, and salicylic acid. The identified flavonoids included catechins, epicatechins, quercetin and its glycoside derivatives (quercetin-3-glucoside, quercetin-3-arabinoside, rutin), as well as myricetin, myricetin-3-rhamnoside, tellurioside, apigenin, chrysin, naringenin, and curcumin. In addition, other bioactive compounds were detected, such as oleanolic acid, oleuropein, resveratrol, β-carotene, and thymol.

This chemical diversity and the integration between flavonoids and phenolic acids replicate the opportunity of a synergistic impact between the compounds, explaining the extended organic efficacy of the extracts[32].

The evaluation consequences printed a clear distinction in the abundance sample between the two extracts. The extract(HPM) recorded excessive percentages of salicylic acid (37.03%), catechin (17.08%), ferulic acid (14.39%), and epicatechin (12.23%). In contrast, the different extract(HPO) used to be characterised through a enormous make bigger and higher abundance of epicatechin (42.30%), observed by means of catechin (15.56%), ferulic acid (12.79%), and Sinapic acid (7.9%).

The predominance of Catechin and epicatechin, which are major flavan-3-ols found in various plant sources, are biologically significant due to their potent antioxidant properties and their ability to interfere with microbial and fungal cell membranes. Several studies have demonstrated that these compounds can disrupt fungal cell wall integrity, inhibit biofilm formation, and reduce microbial virulence, thereby enhancing the susceptibility of microorganisms to antifungal agents. These findings highlight the potential of catechins as natural compounds that modulate oxidative stress and microbial resistance, supporting their consideration in antimicrobial and antifungal strategies[33][34][35].

Ferulic acid, a naturally occurring phenolic compound, has been shown to antifungal activity in vitro by targeting the fungal cell membrane, impairing membrane integrity and inhibiting components required for cell membrane structure[36].As for salicylic acid, a phenolic phytohormone, plays a crucial role in plant immune signaling by activating defense pathways and systemic acquired resistance (SAR), thereby enhancing resistance against a range of pathogens and contributing to overall plant defense responses[37][38]. These biological activities support the contribution of both compounds to improved antimicrobial responses in plant extracts.

The absence of bioactive compounds such as tiliroside, apigenin, chrysin, sinapic acid, and vanillic acid was observed in the extract (HPM), although the extract (HPO) contained a moderate amount of sinapic acid and trace amounts of some of these compounds. This may be attributed to solvent selectivity and the efficiency of extracting different phenolic constituents, which depend on the polarity of the solvent. These factors not only affect the recovery of these compounds but also influence the biological activity of the extract. Studies have indicated that phenolic acids significantly contribute to the antifungal activity of plant extracts, with compounds such as vanillic acid demonstrating inhibitory effects against fungal growth in vitro [39][40]. In addition, flavonoids such as apigenin and chrysin represent a class of polyphenolic compounds with diverse biological activities, including antioxidant, anti-inflammatory, antimicrobial, and cytotoxic effects, confirming their relevance in assessing the therapeutic potential of phenolic-rich extracts [41].

The results of this study are consistent with those reported *by Mona Y. A. Mostafa[40]* and *Heba et al* [42]on the characterization of phenolic compounds in the extract of the heart date palm using HPLC,**(Table 4)** where numbers phenolic compounds were identified, including compounds common to our study, namely caffeic acid, gallic acid, vanillic acid, acid, ferulic acid, catechin, quercetin, and rutin, which supports the reliability of the current analysis and confirms the stability of some phenolic substances in palm hearts with relative differences in concentration.

The noticeable variation in the proportions and presence of compounds in date palm heart extracts is attributed to the influence of a range of environmental, agricultural, and technical factors, including climatic conditions, temperature and humidity, soil type, geographical origin, solar radiation level, stage of ripeness, and harvest date, as well as the type of solvent, extraction techniques, processing methods, and storage conditions. These factors have been shown to directly affect the secondary metabolic pathways of the plant, which is reflected in the final phenolic composition[43].

The consequences of the UPLC-ESI-MS/MS evaluation verify that the date palm coronary heart is a prosperous and varied supply of phenolic and flavonoid compounds with excessive organic activity. The predominance of catechin, epicatechin, ferulic acid, and salicylic acid, enhances the utility workable of these extracts as a promising herbal supply for growing antioxidant and antimicrobial agents, especially antifungal activity.

Table 4 : The results of UPLC-ESI-MS/MS analysis of *heart of palm* extracts.

ID#	Bioactive compounds	Molecular Formula	Extracts of haert palm	
			HPO (%)	HPM (%)
1	Catéchine (-)	C15H14O6	15,56	17,08
2	myricetin	C15H10O8	1,78	2,56

3	Myricetine-3-rhamnose	C27H30O17	0	Trace
4	Quercetine-3-arabinose	C20H18O11	0,84	2,18
5	Quercetine-3-glucoside	C21H19O12	0,72	0,67
6	Tiliroside	C30H26O13	Trace	0
7	Apigénine	C15H10O5	Trace	0
8	Chrysin	C15H10O4	Trace	0
9	Curcumin	C21H20O6	0,25	0,45
10	Epicatechin	C15H14O6	42,30	12,23
11	Ferulic Acid	C10H10O4	12,97	14,39
12	Oleanolic Acid	C30H48O3	1,49	1,98
13	Oleuropein	C25H32O13	0,37	0,41
14	Quercetine	C15H10O7	0,23	0,20
15	Resveratol	C14H12O3	1,06	1,79
16	Rutin	C27H30O16	0,14	Trace
17	Sinapic Acid	C11H12O5	7,9	0
18	beta carotene	C40H56	3,42	4,32
19	kojic acid	C6H6O4	0,79	1,09
20	naringenin	C15H12O5	0,34	0,51
21	Thymol	C10H14O	0,88	0,85
22	vannilin	C8H8O3	1,03	1,02
23	Caffeic Acid	C9H8O4	1,17	0,61
24	Gallic Acid	C7H6O5	0,18	0,33
25	Vanillic Acid	C8H8O4	Trace	0
26	p-Coumaric Acid	C9H8O3	0,35	0,20
27	salicilic acid	C7H6O3	6,06	37,03

Quantitative Analysis:

Determination of TPC and TFC:

Plant-derived polyphenols have garnered significant scientific interest due to their vital role as natural antioxidants. Among these, flavonoids are the most abundant and structurally diverse group, They work in a variety of ways, including scavenging free radicals, inhibiting enzymes that produce radicals, and stopping oxidative chain reactions[40][44]. Table 4 shows the total phenols and flavonoids in the ethanolic extract of palm heart. The total phenolic content (TPC) of the extract of palm heart (HPO) and(HPM) was 16.0204 and 12.0823(mg GAE/g DW), respectively. also determined that total flavonoid content (TFC) 6.47 and 11.36 (mg QE/g DW), respectively. which was This study showed that the extracts have a low phenolic content compared to other studies, such as those of *Trabzuni*et al.[45], who investigated three Saudi date palm heart varieties (Sokari, Nabout Saif, and Soulag). The total phenolic contents recorded for these varieties were 56.05 ± 0.60, 25.90 ± 0.43, and 41.44 ± 0.72 mg gallic acid equivalents (GAE)/100 g, respectively. In addition, the total flavonoid content ranged from 4.86 ± 0.07 to 6.82 ± 0.20 µg quercetin equivalents (QE)/mL.(**Table 5).**

Furthermore, *Mona Y. A. Mostafa[40]* reported that the concentrations of polyphenols and flavonoids in heart of palm extract reached 79.6 mg GAE/g and 37.7 mg QE/g, respectively. In this context, variations in the content and composition of phenolic compounds may be attributed to several factors, including cultivar differences, as well as geographical and environmental conditions.

Table 5. Total phenols and flavonoids of palm heart extract.

Extract of palm heart	TPC (mg GAE/g DW)	TFC (mg QE/g DW),
HPO	16.02	6.47
HPM	12.08	11.36

Antifungal activity

The antifungal activity is determined by evaluating the presence or absence of mycelial growth in various fungal strains. Statistical analysis using variance highlights a highly significant difference ($p<0.0001$) in the mycelial growth observed among the tested fungal strains.

mycelial growth:

According to **Figure 01**, the effect of extract of (HPO) was only observed at concentrations of 16% and 20%, where no growth was obtained for all the fungi strains. Fungal growth slightly decreased with increasing extract concentration compared to the control, with a diameter of 18.7 mm for *F. proliferatum*, and 20.2 mm for *W. anomalus* at a concentration of 13%. At 6 % concentration, a fungal growth diameter of 44.4 mm was recorded for *F. proliferatum* and 39.2 mm for *Wickerhamomyces anomalus*. In the control group, all four strains exhibited growth, reaching a diameter of 50 mm. The minimum inhibitory concentration (MIC) was determined to be 16% for *F. proliferatum*, and *W. anomalus.* The extract HPM shows a maximum fungal growth diameter (50 mm) of *F. proliferatum* and *W. anomalus* was obtained in the control group, corresponding to the absence of extract. Fungal growth was observed for all strains at concentrations of 6%, 9%, and 13% in the presence of the extract. Fungal growth slightly decreased with increasing extract concentration compared to the control. At concentrations of 16% and 20%, a diameter of (0 mm) was recorded for all strains. The minimum inhibitory concentration (MIC) was determined to be 16% for *F. proliferatum* and *W. anomalui*.

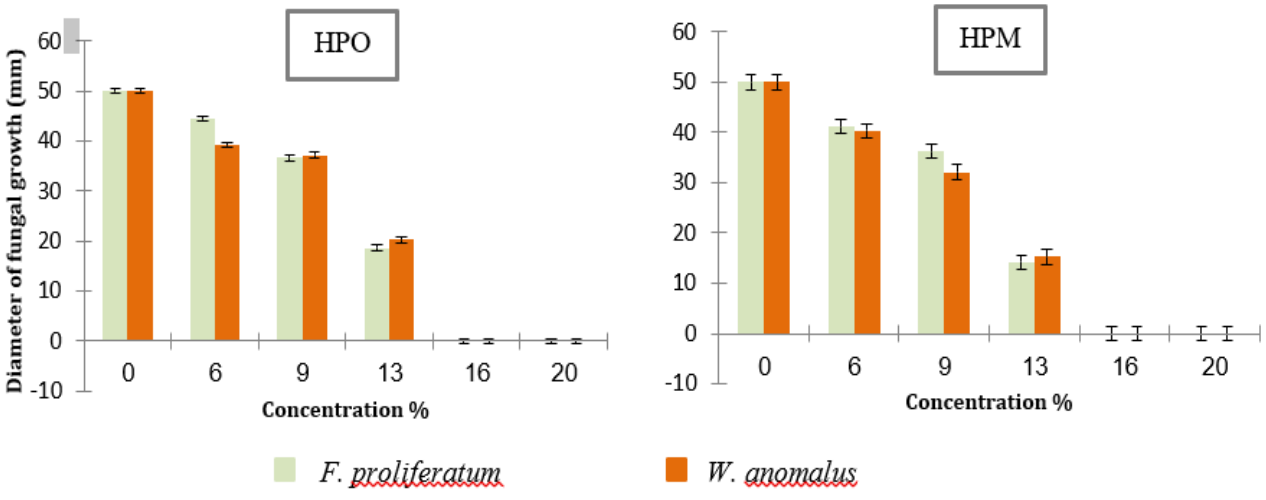


Figure 1: Effect of different concentrations of extract of (HPO and HPM) on mycelial growth.

Antifungal Index:

the results depicted in **Figure 2** represents the antifungal index of the palm heart extracts (HPO and HPM).

The extract of (HPO) effectively inhibits the growth of strains shows 100% inhibition of mycelial growth for *F. proliferatum*, and *W. anomalus* at concentrations of 20% and 16%. and effective inhibition activity was observed at a concentration of13% . We obtained 11,2% inhibition at the concentration of 6% for *F. proliferatum*, and 21,6% for *W. anomalus*. The antifungal index increases as the concentration of the extract increases, reaching 13%. Also the HPM extract shows a complete inhibition (100%) of mycelial growth for all tested strains at concentrations of 20% and 16%. At 13% , we obtained 71.6% inhibition for *F. proliferatum*, and 69.6% for *W. anomalus*.

However, the antifungal index increased proportion with the concentration of extracts.

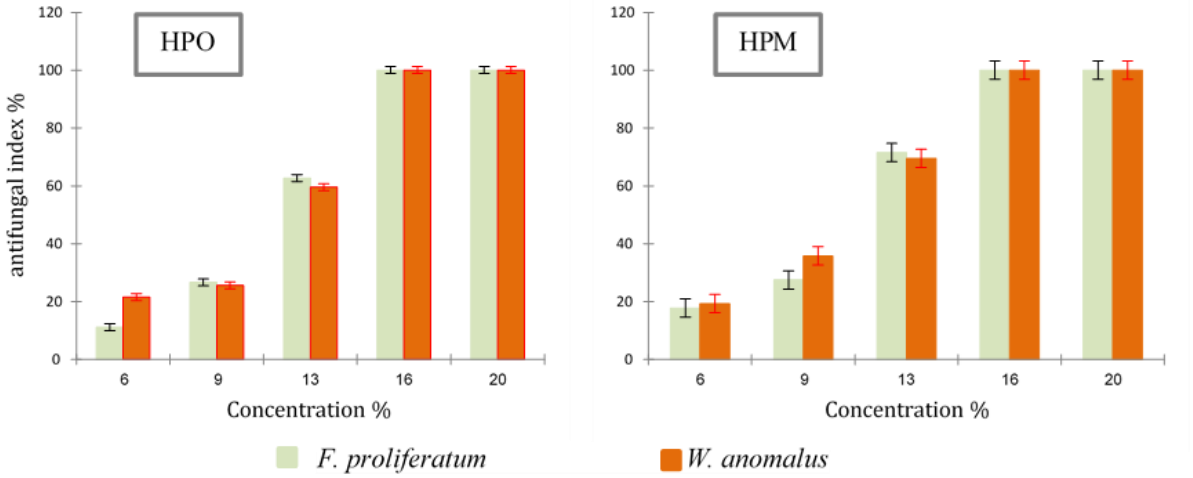


Figure 2: The antifungal index inhibition of different concentrations of extract of (HPO and HPM) on mycelial growth.

The ANOVA analysis results indicated a highly significant effect of hydroethanolic extracts (HPO and HPM) on inhibition of mycelial growth ($p < 0.0001$) **Figure 3**. However, statistically significant differences the antifungal index inhibition between *Fusarium* and *Wickerhamiella* **(Figure 3.a)**, as well as between the both extracts **(Figure 3.a)**, across the different tested concentrations.



Figure 3: a) differences the antifungal index inhibition between Fusarium and Wickerhamiella. b) differences the antifungal index inhibition between the two semple.

A substantial body of literature has demonstrated the antifungal potential of different parts of the date palm (*Phoenix dactylifera* L.). *Bokhari et al* [46] reported that methanolic extracts of seeds and leaves from the cultivars (Barhi and Rothana) exhibited inhibitory activity against seven phytopathogenic fungi, including *Fusarium oxysporum*, *Fusarium sp.*, *Fusarium solani*, *Aspergillus flavus*, *Alternaria alternata*, *Alternaria sp.*, and *Trichoderma sp*. Similarly, *Belmir et al[47]* documented that the aqueous extract of Ajwa date fruits exerted significant antifungal activity against *Candida albicans*, with an efficacy comparable to amphotericin B.

To the best of our knowledge, the present investigation represents the first report assessing the antifungal efficacy of hydroethanolic extracts derived from male date palm heart tissues against two fungal strains implicated in postharvest potato diseases. Our results clearly demonstrate a concentration-dependent inhibition of mycelial growth for both filamentous fungi following treatment with(HPO) and(HPM) extracts, with maximal suppression observed at a concentration of 16%. Comparative evaluation revealed that the tested extracts displayed comparable, and in certain cases superior, antifungal performance. The progressive increase in growth inhibition indices with rising extract concentration confirms a strong positive dose–response relationship.

These findings are consistent with recent evidence reported in *Lahlali et al* [48], where ethanolic extracts of four angiosperm species: *A. albus*, *C. australis*, *O. oleaster*, and *C. humilis* (Amaranthaceae, Cannabaceae, Oleaceae, and Arecaceae, respectively) exhibited significant inhibitory effects against *Penicillium expansum* and *Botrytis cinerea* isolated from decayed apples. The highest suppression of mycelial development was recorded at (300 g/L), particularly against *P. expansum*, confirming the concentration-dependent nature of plant-derived antifungal agents.

In agreement with our results, *Benhaoued et al.*[49] demonstrated a clear dose-dependent antifungal activity of aqueous extracts from *Mentha spicata* L., *Mentha piperita* L., *Mentha pulegium* L., and *Ocimum basilicum* L. against major potato-associated phytopathogens, including *Fusarium proliferatum*, *Alternaria alternata*, *Wickerhamomyces anomalus*, and *Rhizoctonia solani*. Likewise, *Dellouche et al*[50]. reported that traditional Algerian date vinegars: Tantboucht Ghardaia Vinegar (TGV), Deglet Nour Ghardaia Vinegar (DGV), Hchef Ouargla Vinegar (HOV), and Deglet Touggourt Vinegar (DTV) exhibited marked inhibitory activity against *F. proliferatum* and *W. anomalus* across a concentration range of (5%–30%).

Furthermore, *Albandary* [51]demonstrated that crude methanolic extracts of red onion peels effectively inhibited the growth of *Fusarium graminearum* over a concentration range of (250–1000 µg/mL), achieving complete growth suppression at 1000 µg/mL and corresponding to a 77% reduction in linear mycelial growth. A statistically significant positive correlation between extract concentration and antifungal efficacy was confirmed. Moreover, *Mostafa.* [40] demonstrated that date palm heart extracts reported pronounced anti-inflammatory and anticancer activities, reflecting the multifunctional nature of these bioactive compounds.

The results of this study, supported by recent literature, indicate that date palm hearts (Phoenix dactylifera) are rich in phenolic compounds and flavonoids, which play a central role in their multifunctional biological activities, including antioxidant, anti-inflammatory, anticancer, and antifungal effects. These compounds contribute to the regulation of oxidative balance and disruption of fungal cell membranes, increasing permeability and causing ionic imbalance, which explains their antimicrobial efficacy [30][52].

Conclusions

The present study provides compelling evidence that *Phoenix dactylifera* L. heart extracts possess pronounced antifungal activity against major phytopathogenic fungi responsible for postharvest deterioration of potato crops. The observed bioactivity is strongly correlated with the extract's high content of phenolic compounds and flavonoids. These findings highlight date palm heart extract as a promising, eco-friendly, and economically viable plant-derived biopesticide. Its multifunctional biological profile, encompassing antioxidant and antimicrobial properties, reinforces its potential integration into sustainable plant disease management strategies aimed at reducing reliance on synthetic fungicides. Future investigations should focus on molecular mechanism elucidation, toxicity assessment, and field-scale validation to confirm its practical applicability in agricultural systems.

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