1. Introduction

The palm family (Arecaceae) has a long history of providing man with useful materials for his daily life[1]. Chemically, the family has been neglected despite of its economic importance, probably because of difficulty of collecting fresh material and getting it authenticated. The genus *Phoenix* is one of the most widely cultivated groups of palms around the world[2]. *Phoenix roebelenii* O’Brien (*P. roebelenii*) is a species of date palm native to south eastern Asia. It is a popular ornamental plant in gardens and in tropical to warm temperate climate areas and well known as pygmy date palm or miniature date palm. Members of the genus *Phoenix* are characterized by different classes of phenolic compounds (tricin, luteolin and quercitin glycosides) constituting the major leaf components[3]. *Phoenix* species has been used for treatment of various infectious diseases, atherosclerosis, diabetes, hypertension and cancer[4-6]. Phenolic compounds have diverse beneficial biochemical effects on human health. They show antioxidant, hepatoprotective, anticancer and anti-inflammatory activities[7-10].

**Objective:** To authenticate *Phoenix roebelenii* O’Brien, and investigate its leaves and fruits phytoconstituents, antioxidant, hepatotoxicity and hepatoprotective activities.

**Methods:** DNA profiling was carried out by random amplified polymorphic DNA-PCR). Total phenolic contents were estimated using Folin-Ciocalteu method. Chromatographic and spectral techniques were used for the phytochemical investigation. Petroleum ether extracts were investigated using GC-M-S. A nitrosonitroxide activity was assayed by 1, 1-diphenyl-2-picrylhydrazyl radical scavenging method. Hepatotoxicity and hepatoprotective assessments were achieved by neutral red assay.

**Results:** Total phenolic contents of leaves and fruits were estimated as being 64.3 and 7.88 μg gallic acid equivalent/mg, respectively. Ten compounds were isolated for the first time from the aqueous methanol extract of leaves: apigenin 6, 8-di-C-β-glucopyranoside, quercetin 3-O-glucopyranoside, luteolin 3'-O-β-glucopyranoside, quercetin, apigenin, luteolin, baicalein and p-hydroxybenzoic, vanillic and caffeic acids. Major lipophilic constituents of petroleum ether leaves extracts are ricinoleic acid (51.12%) and phytol (10.64%), while those of fruits are linoleic acid (33.61%) and n-octadecanol (9.04%). A aqueous methanol and petroleum ether extracts of leaves and fruits exhibited antioxidant activity at IC$_{50}$ (60.25 and 51.70 μg/mL) and (6.3 and 21.0 μg/mL), respectively. The extracts hepatotoxicity is at IC$_{50}$ > 1000 μg/ml. Leaves and fruits petroleum ether extracts exhibited prominent hepatoctoxic activity > 12.5 and 15 μg/mL, respectively.

**Conclusions:** The palm may be a new potential source as a natural hepatoprotective to be applied in pharmaceutical industries.
neither the phytochemical constituents nor biological activity of *P. roebelenii* O’Brien.

Accordingly, the aim of the present work was to authenticate *P. roebelenii* O’Brien growing in Egypt by carrying out PCR sequencing and to investigate its phenolic and lipoidal constituents. In addition, to *in vitro* investigate antioxidant, hepatotoxicity and hepatoprotective activities of the palm leaves and fruits extracts.

2. Materials and methods

2.1. General experiment

PCR amplification was performed in a Perkin-Elmer/Gene Amp® PCR system 9700 (PE Applied Biosystems). Ultraviolet spectra were recorded on Shimadzu UV 240 (P/N 204-58000). Nuclear magnetic resonance (NMR) measurements were carried out using Jeol EX-500 spectroscopy (Japan): 500 MHz (¹H-NMR) and 125 MHz (¹³C-NMR). Electron ionization mass spectrometry was performed using thermo scientific spectrometer (70 eV). Gas chromatograph-mass spectrometry (GC-MS) analysis were carried on trace GC ultra/ISQ single quadrupole MS, TG-5MS fused silica capillary column (30 m, 0.251 mm, 0.1 mm film thickness). For preparation of petroleum ether extracts, a soxhlet apparatus was used. Column chromatography for isolation of phenolics was carried out on polyamide 6S (Riedel-De-Haën, AG, Sleeze Hanver, Germany) using methanol/H₂O as eluent. Paper chromatography descending Whatman No.1 and 3 mm papers, using solvent systems: (1) water, (2) 15% HOAc (water:acetic acid 85:15), (3) 50% HOAc, (4) BAW (butanol:acetic acid:water, 4:1:5 upper layer) and (5) BBWP (benzene:butanol: water: pyridine 1:5:3:3, upper layer). BAW and BBWP were used for sugar identification. The purification was performed in Sephadex LH-20 (Pharmacia, Sweden). Solvents used for plant extraction were from SDFCL (industrial Estate, 248 Worli Road, Mumbai-30, India). Monolayer of hepatocytes examination was carried out with light microscope (Olympus, Saitama, Japan).

2.2. Chemicals

Methanol and sodium sulphate were from Readel-de Haën. The following compounds were also purchased: 4-(22-hydroxyethyl)-1-piperazine-ethanesulfonic acid (99%) (ACROS Co.), potassium chloride (S.R.L), D (+) glucose (Merck), calcium chloride (S.D), fetal bovine serum (Lonza), penicillin streptomycin (Gibco BRL), sodium thiopental, silymarin (Sigma), sodium chloride, sodium phosphate monobasic, sodium phosphate dibasic, potassium phosphate monobasic, ethylene glycol tetraacetic acid, collagenase type IV, culture medium RPMI-1640, trypan blue, insulin, neutral red and dimethyl sulfoxide (Sigma Co.).

2.3. Plant material

Fresh plant material (leaves and fruits) of *P. roebelenii* O’Brien (Arecaceae) were collected from the Orman garden, Giza, Egypt and identified by Dr. M. El Gibali, former researcher of botany, National Research Centre, Egypt. A voucher specimen (M 126) was deposited in the National Research Centre herbarium.

2.4. Random amplified polymorphic-DNA (RAPD)-PCR

Freeze-dried leaves of *P. roebelenii* were ground under liquid nitrogen to fine powder (50 mg) prior to DNA isolation. DNA was extracted using the cetyltrimethylammonium bromide [1% (w/v) N-cetyl-N, N, N trimethyl ammonium bromide] method[11]. Ten oligonucleotide primers were used for RAPD analysis in this study. PCR products were visualized on UV light and photographed using a Polaroid camera. Amplified products were visually examined and the presence or absence of each size class was scored as 1 or 0, respectively. The banding patterns generated by RAPD-PCR marker analyses were compared to determine the genetic relatedness (Figure 1). The genetic similarity coefficient was estimated according to dice coefficient[12].

2.5. Phytochemical investigation

2.5.1. Determination of total phenolic content of leaves and fruits

Air-dried plant leaves and fruits (1 g each) were extracted with 70% methanol by sonication at room temperature. The total phenolic content of the extracts were determined by the Folin-Ciocalteau method[13]. The total phenolic content was expressed in μg of gallic acid equivalents/mg of extract.

2.5.2. Extraction and isolation

The air-dried powdered palm leaves (1 kg) were extracted with MeOH/H₂O (7:3) by percolation on hot (3 × 4L). The solvent was evaporated under reduced pressure at 60 °C to yield 228 g dried aqueous methanol extract (PLAME). PLAME was defatted with CHCl₃ (3 × 1 L) afforded chloroform extract (12 g). The defatted PLAME residue (180 g) was
extracted with methanol and followed by water (three times for each solvent). The methanol fraction residue (80 g) was chromatographed on polyamide column chromatography (5 cm × 100 cm) using H₂O, followed by H₂O:MeOH mixtures of decreasing polarity to yield ten main fractions (A–I). Fraction B was eluted on Sephadex L20 column using H₂O:MeOH (1:1) then subjected to preparative paper chromatography using BA and followed by elution on Sephadex L20 column using methanol to yield compound 1 (12 mg). Column chromatography of fraction B on polyamide column (gradient elution with CHCl₃/MeOH) gave one major sub-fraction B1. Column chromatography of B1 on Sephadex L20 column using MeOH afforded compound 2 (11 mg). Fraction I was chromatographed on Sephadex column using H₂O:MeOH (1:1) followed by MeOH for elution, afforded compounds 3 (45 mg). Column chromatography of fraction J on polyamide column (2.5 cm × 45 cm), gradient elution with CHCl₃/MeOH, gave four major sub-fractions: J1, J2, J3 and J4, each was subjected to column chromatography on Sephadex L20 using MeOH afforded compounds: 4 (12.5 mg), 5 (5 mg), 6 (4 mg) and 7 (40 mg).

The water fraction residue (30 g) was chromatographed on Sephadex L20 column using H₂O:MeOH (1:1) yielding three major sub-fractions, each was subjected to column chromatography on Sephadex using MeOH to yield compounds 8 (10 mg), 9 (62 mg) and 10 (42 mg). The isolated compounds (1-10) were subjected to chemical and spectroscopic methods of analysis for their structure elucidation[14-16].

2.5.3. GC-MS analysis of the lipophilic fractions

2.5.3.1. Extraction of lipophilic fractions

A total of 50 g of powdered plant leaves and fruits of *P. roebelenii* were extracted with (2500 mL) petroleum ether (60-80 °C) each, by Soxhlet method. The solvent was distilled off under vacuum at reduced temperature 45 °C to yield 3 g leaves petroleum ether extract (PLPEE) and 5 g fruits petroleum ether extract (PFPEE) residues.

2.5.3.2. Saponification of the lipophilic fraction and formation of fatty acid methyl esters

One gram of petroleum ether extract (PLPEE, PFPEE) was saponified according to the method described by Abdeddaim *et al.*[17] by refluxing with alcoholic potassium hydroxide (10%) for 45 min to yield the unsaponifiable matter of leaves (LUSM) and of fruits (FUSM) as well as fatty acids fraction. The fatty acids fraction was subjected to methylation according to the method adopted by Mendonça *et al.*[18] by refluxing with absolute methanol (50 mL) and sulphuric acid (3 mL) for 2 h to yield fatty acid methyl esters of leaves (LFAME) and of fruits (FFAME). The produced LUSM, FUSM, LFAME and FFAME are kept in a desiccator for GC-MS analysis.

2.5.3.3. GC-MS analysis for unsaponifiable matter

A 1 μL unsaponifiable matter sample (LUSM, FUSM) was injected into gas chromatographic apparatus and separation was carried out on DB-5 fused silica (5% phenyl methyl polysiloxane). The carrier gas (helium) pressure was maintained at 13 psi and the column flow rate was 1 mL/min. The oven temperature was maintained at 50 °C isothermal for 3 min, and then heated to 300 °C at a rate of 5 °C/min. The temperature of the injector during the injection was 220 °C.

2.6. Biological assay

2.6.1. Determination of antioxidant activity

Radical scavenging activity of 70% aqueous methanol extract of *P. roebelenii* leaves and fruits were estimated by 1, 1-diphenyl-2-picrylhydrazyl radical assay[19]. The half maximal scavenging capacity (5SC₅₀) values for each extract and ascorbic acid was estimated via dose curve.

2.6.2. Hepatoprotective activity

2.6.2.1. Isolation and culture of rat hepatocytes monolayer

Primary culture of rat hepatocytes was prepared according to Seglen’s method[20], modified by Kiso *et al.*[21], using Wistar male rats (250-300 g) obtained from the animal house of the National Research Center, Cairo. Animal procedures were performed in accordance with the Ethics Committee of the National Research Centre and followed the recommendations of the National Institutes of Health Guide for Care and Use of Laboratory Animals (NIH Publication No. 85-23, revised 1985).

2.6.2.2. Evaluation of hepatotoxicity

After pre-incubation of primary culture of rat hepatocytes for 22-24 h, the monolayer was checked under inverted microscope (Olympus) for attachment. Then, the monolayer was washed twice with phosphate buffer saline (PBS). In order to determine IC₅₀, different concentrations of PLAME, PFAME, PLPEE and PFPEE were prepared. The range of concentrations used started from 125 to 1000 μg/mL that induced death of half the number of cells. *P. roebelenii* extracts were dissolved in dimethyl sulfoxide (1% maximum concentration). For each concentration, three replicates were carried out. The plate was incubated for 2 h in CO₂ incubator. After cell incubation with the extract, cell viability was determined using neutral red assay[22]. A sorbance produced by viable cells was read at 540 and 630 nm dual wavelength using automatic kinetic microplate reader (Labsystems Multiskan RC reader). Each experiment was carried out in triplicate to confirm validity of results. A graph was plotted with x-axis showing different concentrations of extracts used, y-axis showing absorbance percentage of viable cells.

2.6.2.3. Evaluation of hepatoprotective activity

A monolayer from primary cultures of rat hepatocytes was performed
in the 96-well plate, incubated for 22-24 h, washed twice with PBS. Different concentrations were prepared from each of the extracts of _P. roebelenii_, starting from 12.5 μg/mL and increasing concentration in ascending order by dissolving in dimethyl sulfoxide (1% maximum concentration). For each concentration, three replicates were carried out, in addition to controls which were: cell control (cells only), 50% of cell control, paracetamol (25 mmol/L) negative control (cells + paracetamol) and sylimarin (50 μg/mL) positive control (reference) (cells + sylimarin + paracetamol). The plate was incubated for 2 h, washed twice with PBS. Paracetamol (25 mmol/L) was added to each well except on that of the cell control (100% and 50%), and incubated for 1 h. Following incubation, the monolayer was washed again with PBS. The half maximal inhibitory concentration (IC₅₀) was determined using neutral red assay, by comparing the results to that of the control wells that contain: cell control (2 × 10⁶ cells/mL), a total of 50% of cell control (1 × 10⁶ cells/mL) and positive control (cells + sylimarin + paracetamol) which was able to protect the cells from the hepatotoxic effect of paracetamol. The concentration of the extract that was able to protect the cells from the hepatotoxic effect of paracetamol by 100% was considered hepatoprotective.

2.6.2.4. Statistical analysis

All data presented are based on means of triplicate absorbance determinations. Experiments were repeated twice for all samples.

3. Results

3.1. DNA profiling analysis

Total genomic DNA profiling of _P. roebelenii_ O’Brien grown in Egypt was performed using 10 random primers. The number of banding patterns generated by each primer was recorded to obtain the plant was performed using 10 random primers. The number of banding sequences generated 91 fragments in _P. roebelenii_, O’Brien grown in Egypt (Table 1).

The obtained RAPD-PCR products are represented in Figure 1.

3.2. Chemical investigation

3.2.1. Total phenolic content

The total phenolic contents of the aqueous methanol extract of the leaves and fruits of _P. roebelenii_ O’Brien were 64.3 and 7.88 μg of gallic acid equivalents/mg, respectively.

3.2.2. Phenolics from _P. roebelenii_ leaves

Phytochemical investigation of defatted aqueous methanol extracts of _P. roebelenii_ leaves led to the isolation of 10 phenolic compounds identified as: apigenin 6,8-di-C-β-glucopyranoside (1), quercetin 3-O-glucoside (2), luteolin 3’-O-β-glucopyranoside (3), quercetin (4), apigenin (5), luteolin (6), baicalein (7), p-hydroxybenzoic acid (8), vanillic acid (9) and caffeic acid (10) (Figure 2).

3.2.3. Lipophilic constituents of petroleum ether extracts of _P. roebelenii_ leaves and fruits

The GC-MS analysis of _P. roebelenii_ leaves and fruits [unsaponified (LUSM, FUSM) and saponified (LFAME, FFAME)] petroleum ether fractions revealed the presence of 59 and 46 phytochemical compounds, respectively, that could contribute to the medicinal quality of the plant. The identification of the compounds was confirmed on the basis of peak area, retention time and molecular formula. The active principles with their relative retention time, molecular weight and peak area in percentage are presented in Tables 2 and 3. The first compounds identified with less retention time for LUSM and FUSM were hexadecane and tetradecane (0.58, 0.66 relative retention time) respectively, whereas for LSM and FSM, palmitic acid and methyl 14-methyl-pentadecanoate were the last compounds appearing at relative retention time (0.66, 0.8) respectively.

3.3. Biological assay

3.3.1. Antioxidant assay

_P. roebelenii_ leaves and fruits aqueous methanol extracts
3.3.2. Hepatotoxicity

The viability assay was applied with a broad range of concentrations of the aqueous methanol and petroleum ether extracts of *P. roebelenii* O'Brien leaves and fruits (from 125-1000 μg/mL) on monolayer of rat hepatocytes. The assay revealed that the extracts (PLAME, PFAME, PLPEE and PFPEE) hepatotoxicity were at an IC\textsubscript{50} > 1000 μg/mL. (Figure 3).

![Figure 3. Viability of monolayer of rat hepatocytes after 2 h treatment with different concentrations of *P. roebelenii* extracts using neutral red colourimetric assay. Each point represents the mean ± SD (n = 3).](image-url)
**3.3.3. Evaluation of hepatoprotective activity applying rat hepatocyte monolayer**

The hepatoprotective effect of the tested extracts against paracetamol toxic effect using neutral red colourimetric assay showed that PLPEE and PFPEE have exerted hepatoprotective effects at concentrations >12.5 and 15 μg/mL, respectively. While, PLAME and PFAME did not show hepatoprotection activity till the maximum concentration tested (100 μg/mL) (Figure 4).

![Figure 4](image-url) 

**Conflict of interest statement**

We declare that we have no conflict of interest.

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