Antioxidant and Intracellular Reactive Oxygen Species/Reactive Nitrogen Species Scavenging Activities of Three Porcupine Bezoars from Hystrix brachyura

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INTRODUCTION

Free radicals such as reactive oxygen species (ROS) and reactive nitrogen species (RNS) are generated endogenously by enzymes and metabolic activities and exogenously through exposure to chemical and radiation. Free radicals take part in facilitating various pathological conditions such as neurodegenerative diseases, chronic kidney diseases, and diabetes through damaging physiological macromolecules including DNA, proteins, and lipids. Antioxidants have showed to potentially reduce or prevent the oxidative damage caused by free radicals which significantly impact the progression of these pathological condition. However, endogenous antioxidants such as glutathione are sometimes insufficient to overcome the generation of free radicals in hctic metabolic condition, especially during the time of diseases and infections. Hence, dietary intake of antioxidants is sometimes required to counter against excessive free radicals in the body.

Porcupine bezoars/dates are phytobezoar stones that are used in Traditional Chinese Medicine (TCM) treatments against cancer, postsurgical recovery, dengue fever, etc. The medicinal values have not been scientifically investigated due to the availability and high pricing of the dates. Objectives: This paper represents the first report on the phytochemical content, in vitro antioxidant and intracellular reactive oxygen species (ROS)/reactive nitrogen species (RNS) scavenging properties of the extracts of three porcupine dates: grassy date (GD), black date (BD), and powdery date (PD). Materials and Methods: Dried samples were extracted with methanol and lyophilized. Samples were screened for phytochemical constituents, in vitro antioxidant assays based on total phenolic content (TPC), free radical scavenging, and ferric reducing power (FRP) as well as intracellular ROS and RNS scavenging properties. Results: Phytochemical screening and total tannins assay revealed that tannins, cardiac glycosides, and terpenoids were found in all porcupine dates with tannins forming the major portion of the TPC. In comparison to GD, BD and PD were found to contain significantly high TPC, radical scavenging activity, and FRP At 200 μg/mL, BD and PD remarkably scavenged 2, 2-azobis (2-amidinopropane) dihydrochloride-induced ROS in RAW264.7 cells and significantly reduced nitric oxide in lipopolysaccharide-stimulated cells. Conclusion: Overall, BD and PD exhibited promising in vitro antioxidant as well as intracellular ROS/RNS scavenging properties.

SUMMARY

• Tannins, cardiac glycoside, and terpenoids were found in all three types of porcupine dates with tannins being the major compounds
• Antioxidant contents and properties of three dates were in the order black date (BD) > powdery date (PD) > grassy date
• BD and PD extracts showed significant intracellular reactive oxygen species and reactive nitrogen species scavenging properties.

ABBREVIATIONS USED

TCM: Traditional Chinese Medicine, BD: Black date, GD: Grasssy date, PD: Powdery date, TPC: Total phenolic content, FRP: Ferric reducing power, NO: Nitric oxide, ROS: Reactive oxygen species, RNS: Reactive nitrogen species, GAE: Gallic acid equivalent, AAE: Ascorbic acid equivalent, PVPP: Polyvinylpolypyrrolidone, DCFH-DA: Dichloro-dihydro-fluorescein diacetate, AAPH: 2, 2-azobis (2-amidinopropane) dihydrochloride, LPS: Lipopolysaccharide

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text by hill tribes in Southern China and Southeast Asia. In modern Traditional Chinese Medicine (TCM), it is used by Asian Chinese as a last resort medicine to treat various forms of cancer, dengue fever, meningitis, herpes, throat infection, pneumonia, diabetes, etc. In spite of its extensive usage among the Chinese community in Malaysia and other Southeast Asian countries, scientific verification of its efficacy has not been reported. In this study, we investigated three types of porcupine dates: grassy date (GD) with closely packed grassy and thread-like structure; black date (BD), a compact black solid with remnant of undigested shells; and powdery date (PD), a slightly reddish sphere composed of multiple layers and powdery on the outer layer [Figure 1]. These different types of porcupine dates are popular among Malaysian TCM users and type-dependent medicinal effects were illustrated from the users’ informal testimonies. Through various chemical, biochemical, and cell-based assays, our study for the first time provided evidences on the phytochemical constituents, in vitro antioxidant and intracellular ROS/RNS scavenging properties which underlie the differential medicinal effects of these porcupine dates.

**MATERIALS AND METHODS**

**Sample extraction**
Methanol was used as solvent for extraction due to its ability to dissolve plant phenolics. Approximately 5 g of different porcupine date samples supplied by a traditional Chinese herbs selling company, Soon Hing Cheong Ginseng, were ground into homogenous fine powder using laboratory pestle and mortar. Two hundred milligrams of each sample was extracted using 10 ml of methanol through continuous swirling on orbital shaker for 1 h at room temperature. Extracts were isolated was extracted using 10 ml of methanol through continuous swirling with a solid matrix binding agent polyvinylpolypyrrolidone (PVPP). The tannins–PVPP complex was removed using centrifugation, producing a tannins free extract. TPC activity was calculated based on a standard curve constructed using gallic acid, \( y = 0.0093x (R^2 = 0.9993) \), where \( y \) is absorbance and \( x \) is the concentration of gallic acid in ppm. The TPC is expressed as mg gallic acid equivalent (GAE) per g of porcupine date.

2, 2-diphenyl-1-picrylhydrazyl free radical scavenging activity assay
Free radical scavenging activity (FRS) utilizing 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical was determined using a modified method as previously described. Different dilutions of methanol extracts in 100 µL were added with 200 µL of DPPH (5.9 mg/100 mL 100% methanol). By monitoring absorbance at 517 nm after 30 min incubation in the dark, \( IC_{50} \) concentration of extract required to destroy 50% of the radical was obtained. Ascorbic acid was used as the standard with \( IC_{50} \) scavenging activity of 0.00374 mg/mL. FRS activity expressed as ascorbic acid equivalent (AAE), was calculated as \( \frac{IC_{50}(ascorbate)}{IC_{50}(sample)} \times 10^3 \), and expressed in mg ascorbic acid/g sample.

Ferric reducing power assay
Different dilutions of sample in 100 µL were added with 250 µL phosphate buffer (0.2 M, pH 6.6) and 250 µL of potassium ferricyanide (1% w/v). Following 20 min incubation on a 50°C heating plate, 250 µL of trichloroacetic acid (10% w/v) was added. The solution was pipetted into aliquot of 250 µL and added with 250 µL of ddH2O. Subsequently, 50 µL of ferric chloride solution (0.1% w/v) was added and mixture was left standing for 30 min at room temperature. One hundred microliter of each of the mixture was aliquoted into 96-well plate before measuring absorbance at 700 nm. Results are expressed as mg GAE/g based on calibration equation using gallic acid, \( y = 0.0038x + 0.01 \), where \( y \) is absorbance and \( x \) is concentration of gallic acid in ppm.

**Total tannins content assay**
Total tannins were determined using method as described in Makkar et al. Tannins contents in the methanolic extract of BD and PD were isolated using a solid matrix binding agent polyvinylpolypyrrolidone (PVPP). The tannins-PVPP complex was removed using centrifugation, producing a tannins free extract. TPC assay was performed using Folin–Ciocalteu’s reagent before and after PVPP treatment. The difference between the two TPC values gave the total tannins content in terms of GAE.

**Intracellular reactive oxygen species scavenging activity assay**
Intracellular free radicals scavenging was studied in RAW264.7 cells using dichloro-dihydro-fluorescein diacetate (DCFH-DA) assay as described by Sittisart and Chitsomboon. RAW264.7 cells (4 × 10^4 cells/well) were plated in a SPL 96-well black plate for 16-18 h. Cells were washed twice with phosphate-buffered saline (PBS) before pretreated with BD, PD (200 µg/mL) extracts, and curcumin (5 µM) for 24 h. After incubation, cells were washed twice with PBS before exposed to 20 µM DCFH-DA in Hank’s balanced salts solution (+), followed by 45 min incubation in dark. On addition of ROS stimulator 2, 2-azobis (2-amidinopropane) dihydrochloride (AAPH), fluorescence intensity was measured as earlier described. One milligram of crude extract was weighed in an Eppendorf tube and dissolved in 1 ml of methanol. Using a 96 well-plate, 30 µL of dissolved extract (triplicate) was aliquoted into separate wells, followed by 150 µL of Folin-Ciocalteu’s reagent (10 times dilution) and 120 µL sodium carbonate anhydrous (7.5% w/v). Test tubes were incubated at room temperature for 30 min before absorbance measurement at 765 nm using a Tecan Infinite M200 microplate reader. TPC activity was calculated based on a standard curve constructed using gallic acid, \( y = 0.0093x (R^2 = 0.9993) \), where \( y \) is absorbance and \( x \) is the concentration of gallic acid in ppm. The TPC is expressed as mg gallic acid equivalent (GAE) per g of porcupine date.

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**Figure 1:** Physical classification of grassy date, black date, and powdery date
kinetically for 1 h with 5-min interval at excitation wavelength of 485 nm and emission wavelength of 535 nm using Tecan Infinite M200 microplate reader.

**Reactive nitric oxide scavenging activity**
To determine nitric oxide (NO) scavenging capacity, Griess reagent was used to measure the stable nitrite, NO$_2^−$ which is an intermediate of NO reaction. Approximately 5 × 10$^5$ cells/well in 100 μL of RAW264.7 was plated into a 96-well plate for 24 h. Cells were costimulated with 1 μg/mL of lipopolysaccharide (LPS) at different concentration of sample extracts (0.2–0.0125 mg/mL) for 24 h. Medium supernatants were then collected and analyzed for nitrite amount using 10 μL/well of Griess reagent kit (Life Technologies, 1% sulfanilamide and 0.1% naphthylethlene diaminedihydrochloride in 2% phosphoric acid). Absorbance was measured with microplate reader (Tecan Infinite M200) at 548 nm. The production of nitrite was quantified based on equation of standard curve generated using sodium nitrite (NaNO$_2$), $y = 0.0006x − 0.005$, where $y$ is absorbance and $x$ is concentration of nitrite (1–100 μM).

**Statistical analysis**
All data were plotted and analyzed using GraphPad Prism 6 software (GraphPad Software, Inc., San Diego, USA). Data analyses were done using one-way ANOVA with Tukey’s post hoc test ($P < 0.05$).

**RESULTS**

**Yield of extraction**
The total yields of methanol extract were found to be 48.2% (BD), 39.0% (GD), and 35.5% (PD) based on one-time extraction with 1:50 sample: solvent ratio (w/v).

**Phytochemical constituents**
To determine the phytochemicals present in different kind of porcupine bezoars, we performed a series of phytochemical tests and results are summarized in Table 1. Hydrolysable tannins, cardiac glycosides and terpenoids were found in all three porcupine date extracts while flavonoids only present in BD and PD. It is important to note that phytochemical tests of BD and PD are much more positive (e.g., more intense color) as compared to GD, which give an approximate estimate of their relatively low phytochemical content.

**Total phenolic content, free radical scavenging, and ferric reducing power**
The TPC and radical scavenging activities of BD, PD, and GD were determined using TPC and FRS assays along with standard antioxidants, gallic acid, and ascorbic acid, respectively. FRS activity was determined by measuring the dose-dependent DPPH radical scavenging activity [Figure 2] and the IC$_{50}$ values (6.61, 13.1, and 1467 μg/ml for BD, PD, and GD, respectively) obtained were converted to AAE [Table 2]. The antioxidant content and activities arranged in descending order are BD > PD > GD. BD extract has significantly highest antioxidant content with TPC (188.1 ± 6.2 mg GAE/g), followed by PD which is slightly lower with TPC (104.9 ± 2.9 mg GAE/g) [Table 2]. However, TPC of GD is significantly much lower as compared to BD and PD. Interestingly, TPC values are correlated to their FRS activity. Ferric reducing power (FRP) assay demonstrating electron donating capacity of BD, PD, and GD was analyzed along with standard antioxidant gallic acid. Similarly, BD and PD show 6-fold higher FRP activity than GD [Table 2]. Due to relatively low antioxidant contents and properties, GD was excluded in subsequent cell-based assays.

**Total tannins content assay**
Preliminary phytochemicals screening showed high amounts of tannins in two types of porcupine dates. Total tannins content assay was performed to identify the amount of tannins present in porcupine dates relative to respective TPC. Table 3 summarizes the estimated percentage of tannins contents present in BD and PD by comparing the TPC before and after the removal of tannins using PVPP. It was observed that the major phenolic contents in BD and PD consisted of tannins (~93%).

**Intracellular reactive oxygen species scavenging activity of black date and powdery date**
DCFH-DA assay was used to study the direct scavenging effect of intracellular free radical in AAPH-stimulated RAW264.7. Intracellular cleavage of DCFH by oxidative radical produces a green fluorescence product (DCF) that was measured every 5 min for a duration of an hour. A time-dependent increase of fluorescence signal was observed in all treatments, which were normalized into percentage of fluorescence intensity based on AAPH-stimulated control [Figure 3]. BD and PD at a concentration of 200 μg/ml demonstrated significant decrease in AAPH-induced fluorescence signal of 11.1% and 28.0%, respectively, at the 60-min endpoint. As a comparison, well-studied antioxidant curcumin (5 μM or 1.84 μg/ml) demonstrated 25.8% reduction of fluorescence at the 60 min endpoint of the experiment. Comparatively, PD-treated cells are more effective in reducing the AAPH-stimulated fluorescence intensity as compared to BD, suggesting better intracellular ROS scavenging capability.

**Total phenolic content test**

| Phytochemical test                              | GD  | BD  | PD  |
|------------------------------------------------|-----|-----|-----|
| Alkaloids                                      |     |     |     |
| Wagner’s reagent test                          |     |     |     |
| Mayer’s reagent test                           |     |     |     |
| Draggendorf’s reagent test                     |     |     |     |
| Flavonoids                                    |     |     |     |
| Shinoda test (flavanols, flavones)             |     |     |     |
| Flavonoid test                                |     |     |     |
| Cardiac glycosides/deoxysugar                  |     |     |     |
| Keller–Klliani test                            | +   | ++  | +   |
| Kedde test                                    | +   | ++  | +   |
| Quinones                                      |     |     |     |
| Quinone test                                  |     |     |     |
| Tannins                                      |     |     |     |
| Ferric chloride test (condensed and hydrolysable tannins) | +   | ++  | +   |
| Gelatin test                                  |     |     |     |
| Vanillin test (condensed tannins)              |     |     |     |
| Terpenoids                                    |     |     |     |
| Salkowski test                                |     |     |     |
| Liebermann–Burchard test                      |     |     |     |
| Saponins                                     |     |     |     |
| Foam test                                    |     |     |     |

*: Absent; +: Present in small amount; ++: Present in significant amount as judged by the intensity of the colored solution; GD: Grassy date; BD: Black date; PD: Powdery date
DISCUSSION

Based on the phytochemical tests, we have identified various phytochemicals content in porcupine dates, including but not limited to cardiac glycosides, terpenoids, flavonoids, and tannins. We found all three types of porcupine dates tested in this study contain similar types of phytochemicals except that flavonoids were absent in GD. Among all, cardiac glycosides, often found in plants such as Digitalis, Strophanthus, and Scilla, possess antiarrhythmic properties and are used in treatment of congestive heart diseases.\(^{26,27}\) The presence of cardiac glycosides in the extract of porcupine dates suggests their potential action on the heart functionality. In addition, terpenoids are the largest class of natural products with more than 40,000 known compounds.\(^{28}\) Being abundant in plants, terpenoids together with flavonoids and tannins have been well known as free radical scavengers.\(^{29,30}\) In concordance with the rich phenolic content, we observed both BD and PD showed comparable in vitro antioxidant properties to that of Camellia sinensis tea leaf extract,\(^{23}\) which is known for its high antioxidant property.

When antioxidant properties are expressed as per gram of porcupine dates, our study showed the antioxidant properties of BD sample (TPC: 90.7 ± 3.0 mg GAE/g; FRS: 272.6 ± 11.9 mg AAE/g; FRP: 47.23 ± 0.81 mg GAE/g)\(^{[2]}\) and PD sample (TPC: 40.9 ± 1.1 mg GAE/g; FRS: 101.1 ± 0.5 mg AAE/g; FRP: 34.64 ± 0.35 mg GAE/g)\(^{[2]}\) were comparable to those reported in oolong tea extract. Hot water extract of the tested oolong teas was reported to contain high TPC (TPC range: 75.0 ± 4.6 to 90.9 ± 4.6 mg GAE/g of dried leaves) and possessed high FRS activities (FRS range: 144.5 ± 30.5 to 161.7 ± 24.8 mg AAE/g of dried leaves).\(^{[23]}\) Notably, BD contains two times more active in FRS activity when compared to oolong teas. In contrast, GD was found to contain the least amount of total phenolic compounds (TPC: 9.9 ± 1.6 mg GAE/g). In the antioxidant assays, the lowest FRS activity (FRS: 0.99 ± 0.05 mg AAE/g) and the weakest FRP were also observed for GD (FRP: 6.23 ± 0.01 mg GAE/g) in parallel with its low phenolic content\(^{[2]}\). These findings imply that antioxidant properties of porcupine dates could possibly be contributed by varied amount of phenolic compounds in different porcupine dates.

Our study provided explicit evidences to show that BD contains the highest amount of TPC (~7 times higher than GD) followed by PD (~4 times higher than GD) together with significant higher radical scavenging activity and FRP. Through total tannins content test, we revealed that tannins are the major phenolic compounds consisting of 93.6% ± 0.7 and 93.0% ± 0.4 of the TPC in BD and PD, respectively. Tannins are macromolecule abundantly found in oak tree bark\(^{31,32}\) which is a common diet of porcupine (Hystrix\(^{sp.}\)) in tropical and subtropical regions of Southeast Asia, oak trees from subgenus Cyclobalanopsis are

![Figure 2: Dose-dependent 2, 2-diphenyl-1-picrylhydrazyl radical scavenging activity of methanol extracts of grassy date, black date and powdery date](image_url)

**Table 2:** Total phenolic content, free radical scavenging, and ferric reducing power antioxidant activity of methanolic extracts of black date, grassy date, and powdery date

| Methanol extracts | TPC (mg GAE/g) | FRS (mg AAE/g) | FRP (mg GAE/g) |
|------------------|---------------|---------------|---------------|
| BD               | 188.1±6.2\(^a\) (90.7±3.0) | 565.5±24.8\(^a\) (272.6±11.9) | 97.95±1.6\(^a\) (47.23±0.81) |
| GD               | 27.9±4.6\(^b\) (9.9±1.6) | 2.55±0.12\(^b\) (0.99±0.05) | 15.94±0.04\(^b\) (6.23±0.01) |
| PD               | 104.9±2.9\(^c\) (40.9±1.1) | 284.7±1.33\(^c\) (101.1±0.5) | 97.53±0.99\(^c\) (34.64±0.35) |

Different letters indicate significant difference at \(P<0.05\) determined using one-way ANOVA. The bracketed values are in mg/g of porcupine date sample and the nonbracketed values are in mg/g of extract. TPC: Total phenolic content; FRS: Free radical scavenging, FRP: Ferric reducing power; GD: Grassy date; BD: Black date; PD: Powdery date; GAE: Gallic acid equivalent; AAE: Ascorbic acid equivalent

**Table 3:** Percentage of tannins and nontannins phenolic in methanol extract of black date and powdery date in relative to its total phenolic content determined using Folin-Ciocalteau’s reagent

|                  | BD          | PD          |
|------------------|-------------|-------------|
| Percentage tannins of TPC | 93.6±0.7   | 93.0±0.4   |
| Percentage nontannins of TPC | 6.43±0.72  | 7.03±0.37  |

TPC: Total phenolic content; BD: Black date; PD: Powdery date
commonly found.[33,34] We believe those tannins contained in porcupine diet which are undigested might have been highly concentrated and incorporated into the dates during its formation in the stomach. Chemically, tannins have a structure with numerous hydrolysable moieties such as gallic and ellagic acids which contribute to the high antioxidant properties.[35,36] Therefore, the high content of tannins may be the major factor that underlies the remarkable antioxidant activities of BD and PD. Intriguingly, these dates also showed significant intracellular ROS scavenging activity in RAW264.7 murine macrophage cells.

On the other hand, we observed apparent effects of BD and PD in suppression of NO induced by LPS in RAW264.7 cells. NO is a key RNS that serves as intermediary in several physiological processes including immune regulation in the body. Deregression of NO could lead to various inflammatory diseases.[37‑41] Antioxidants that are able to scavenge NO were found to suppress inflammatory responses through preventing release of pro-inflammatory mediators bradykinin and histamine[42‑44] as well as preventing improper infiltration of leukocytes, mast cells, and macrophages.[42,45,46] Many local medicinal plants which show antioxidant activities are also found to inhibit reactive NO, for instance Clinacanthus nutans, which is commonly known as snake grass.[47,48]

In our laboratory, methanol extract from snake grass was found to significantly inhibit LPS-induced NO production (IC_{50} 230 µg/ml) in RAW264.7 cells (unpublished data). For porcupine dates, we observed comparable NO scavenging activities in the macrophage cells treated with extracts from BD and PD (IC_{50} 165 and 290 µg/ml) suggesting their potential anti-inflammatory properties. Notably, higher NO scavenging activity observed in BD-treated cells was in concordance with its high content of TPC and remarkable antioxidant properties.

CONCLUSION

In conclusion, phytochemicals such as tannins, terpenoids, and cardiac glycosides were found in all three types of porcupine dates. In comparison to GD, the BD and PD contain highest amount of TPC and show remarkable activities in scavenging free radical and reducing iron (III) ions. At the same time, intracellular ROS/RNS induced in murine macrophage cells was also found to be significantly suppressed by BD and PD. The ability in scavenging NO suggests the potential anti-inflammatory properties of these porcupine dates. Further work is in progress to determine the antiproliferative and antiviral activities of the porcupine dates.

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Conflicts of interest
There are no conflicts of interest.

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