In vitro Evaluation of Antioxidant Potential of Isolated Compounds and Various Extracts of Peel of Punica granatum L.

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ABSTRACT
Background: Punica granatum L. (Lythraceae) peel has been proven to exhibit widespread pharmacological application against multitude of disease due to the presence of bioactive principles. Objective: The objective is to isolate the bioactive compounds from the pericarp of P. granatum and to evaluate the antioxidant activity of various extracts. Materials and Methods: Dried peel of P. granatum was extracted with aqueous acetone and chromatographed on Diaion HP-20. Enriched fractions were rechromatographed on Sephadex LH-20 and purified on preparative high-performance liquid chromatography to identify individual compounds. The dried peel was extracted with different solvents to evaluate the antioxidant activity of the extracts. Results: On the chemical investigation, three compounds were isolated and characterized as punicalagin, 2,3-((S)-hexahydroxydiphenoyl)-D-glucose, and punicalin, using various spectroscopic techniques. Conclusion: Results indicate that the isolated compounds have possessed antioxidant activity, and aqueous, methanol, and aqueous acetone extract showed significant scavenging of 2,2-diphenyl-1-picrylhydrazyl and 2,2’-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid) radicals. Key words: 2,3-((S)-hexahydroxydiphenoyl)-D-glucose, antioxidant, nuclear magnetic resonance, Punica granatum

SUMMARY
• In vitro antioxidant activity of Punica granatum extracts was evaluated by 2,2-diphenyl-1-picrylhydrazyl and 2,2’-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid) assay.
• Dried peel of P. granatum was extracted with different solvents to evaluate the antioxidant activity of the extracts.
• Aqueous acetone extract was found to be most active and chromatographed further to afford punicalagin, 2,3-((S)-hexahydroxydiphenoyl)-D-glucose, and punicalin.
• The presence of antioxidant properties of three compounds in the peel of P. granatum has been demonstrated.

INTRODUCTION
Natural products have proven to be an alternative and potential source of synthetic drugs.1,2 Research outcomes have exhibited that crude extracts or purified chemical constituents of various medicinal plants were more effective antioxidants than some synthetic antioxidants.3,4 Punica granatum found to be rich in the phenolic compound may contribute directly to antioxidant activity due to the presence of hydroxy functional groups around the nuclear structure that are potent hydrogen donators.5 Plants have been used traditionally for many centuries for preventing diseases, and recent scientific studies have shown that the existence of a good correlation between traditional or folkloric application of some of these plants further strengthens the search for pharmacologically active compounds from plants.6

P. granatum L. is a shrub or small tree belonging to the family Lythraceae, and its fruit is a rich source of bioactive phytochemicals such as tannins (punicalin, pedunculagin, punicalagin, gallic acid, galagic acid, and ellagic acid esters of glucose) and other phenolics including flavonoids. It is native from the Himalayas in Northern India to Iran but has been cultivated and naturalized over the entire Mediterranean region and has been used extensively in folk medicine of some countries in Asia and other parts of the world.7 Phenolic compounds from plants exhibit various physiological properties such as anti-allergenic, anti-inflammatory, antimicrobial, antioxidant, antithrombotic, cardioprotective, and vasodilatory effects.8,9,10 P. granatum fruits contain secondary metabolites such as tannins, alkaloids, flavonoids, steroids, phenolics, terpenes, volatile oils, mineral elements, amino acids, glycosides, and this is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

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sterols which are responsible for wide variety of activities.[8,12] This has created interest among researchers, product developers, and consumers on pomegranate plant.[13] This study was focused on the evaluation of the antioxidant activity of various extracts and isolation of bioactive compounds from the fruit peel of *P. granatum*.

**MATERIALS AND METHODS**

**Plant material**

Fresh fruits of *P. granatum* were collected from Nilgiris District, Tamil Nadu, India, and identified by Dr. Santhan, Taxonomist, Natural Remedies Pvt Ltd., Bengaluru. A voucher specimen has been deposited at the Agronomy Department of Natural Remedies Pvt. Ltd., Bengaluru.

**General experimental procedures**

High-performance liquid chromatography (HPLC) study was carried out using Shimadzu HPLC system LC-2010HT with ultraviolet and photodiode array detector in combination with Class LC solution software and Kromasil C18 preparative HPLC column (250 mm × 21.2 mm, 5 μ). An isocratic method of 5% Acetonitrile in water was used as mobile phase. This purification step afforded the Compound 3 (265 mg), which was identified as punicalin (α + β) [Figure 2]. The isolated compounds were identified by comparison with the previously reported spectral data.[14,15]

**Punicalagin (Compound 1)**

Dark yellow powder; m/z 1083.42[M-H]; α-isomer-1H NMR (400 MHz, Acetone) δ 7.03 (1H, s, Hd), 6.60 (1H, s, Hc), 6.58 (1H, s, Hb), 5.61 (1H, s, Ha), 5.21 (1H, t, J = 9.6 Hz, H-3), 5.12 (1H, H-1, 4.83 (1H, m, H-2), 4.77 (1H, m, H-4), 4.19 (1H, m, H-6b), 3.28 (1H, br t, J = 9 Hz, H-5), 2.10 (1H, m, H-6a). 13C NMR (300 MHz, Acetone) δ 168.46 (C-7), 167.83 (C-7), 167.4(C-7), 166.94(C-7), 157.2 and 156.66 delta-lactone, 89.45(C-1), 76.1(C-3),73.65(C-2), 70.34(C-4), 66.15(C-6), 63.39(C-6).

β-isomer-1H NMR (400 MHz, Acetone) δ 7.16 (1H, s, Hd), 6.66 (1H, s, Hc), 6.59 (1H, s, Hb), 6.51 (1H, s, Ha), 4.88 (1H, t, J = 9 Hz, H-3), 4.81 (1H, m, H-4), 4.67 (1H, m, H-1), 4.63 (1H, d, H-2), 4.22 (1H, m, H-6b), 2.67 (1H, t, H-5), 2.19 (1H, m, H-6a). 13C NMR (300 MHz, Acetone) δ 168.46 (C-7), 167.83 (C-7), 167.4(C-7), 166.94(C-7), 157.2 and 156.66 delta-lactone, 93.6 (C-1), 78.14(C-3), 75.64 (C-2), 71.85 (C-5), 70.11 (C-4), 63.39(C-6).

2,3-(S)-Hexahydroxydiphenoyl-D-glucose (Compound 2)

Dark yellow powder; m/z 481.42 [M+H]; α-isomer-1H NMR (400 MHz, DMSO) δ 6.43 (1H, S, ArHb), 6.329 (1H, S, ArHa), 5.24 (d, 2.4, H-1), 5.096 (9.6, H-3), 4.70 (1H, dd, J = 2.8 and 9.6 Hz, H-2), 3.73 (1H, m, H-5), 3.68 (1H, m, H-6), 3.50 (1H, m, H-4), 3.37 (1H, m, H-6b), 13C NMR (100 MHz, DMSO) δ 168.9 (C-7), 168.5 (C-7), 144.5(C-4), 144.5(C-4), 144.2(C-6), 144.1(C-6), 134.8 (C-5'), 134.7 (C-5), 125.3(C-2), 124.76 (C-2'), 113.7 (C-1'), 113.6 (C-1), 113.4 (C-3'), 105.1(C-3), Glu δ 89.6 (C-1), 77.05(C-3), 76.5 (C-2), 72.1(C-4), 66.5(C-5), 60.2(C-6).

β-isomer-1H NMR (400 MHz, DMSO) δ 6.44 (1H, s, ArHb), 6.32 (1H, s, ArHa), 4.92 (1H, m, H-1), 4.82 (1H, m, H-3), 4.47 (1H, t, J = 9.25, H-2), 3.70 (1H, m, H-6), 3.652 (1H, m, H-4), 3.57 (1H, m, H-5), 3.37 (1H, m, H-6), 13C NMR (100 MHz, DMSO) δ 168.9 (C-7), 168.5 (C-7), 144.5(C-4), 144.5(C-4), 144.2(C-6), 144.1(C-6), 134.8 (C-5'), 134.7 (C-5), 125.3(C-2), 124.76 (C-2'), 113.7 (C-1'), 113.6 (C-1), 113.4 (C-3'), 105.1(C-3), Glu δ 93.1 (C-1), 79.4 (C-3), 76.8 (C-2), 74.1(C-4), 66.9 (C-5), 60.4(C-6).

**Punicalin (Compound 3)**

Yellowish-green powder; m/z 781.50 [M-H ]; α-isomer-1H NMR (400 MHz, Acetone) δ 4.78 (1H, d H-1), 4.332 (1H, m, H-6b), 4.046 (1H, t, J = 11.1 Hz, H-4), 3.94 (1H, t,J = 10.2 Hz, H-3), 3.32 (d, J = 8.5 Hz H-2), 3.141 (1 H, m, H-5), 2.751 (1H, d, 6a), 13C NMR (300 MHz, Acetone) δ 168.45 C-7', 4. 6-galaglyl, 66.86 C-7', 157.28 and 146.89 lactones, 87.67 (C-1), 74.14(C-3), 71.97 (C-2), 71.73 (C-3), 68.36(C-5), 62.22(C-6).

β-isomer-1H NMR (400 MHz, Acetone) δ 4.37 (1H, m, H-1), 4.306 (1H, m, H-6b), 4.16 (1H, t, J = 9 Hz H-4), 3.47 (1H, t, J = 7.5 Hz H-3), 3.07 (1H, m, H-2), 2.997 (1 H, m, H-5), 2.53 (1H, m, 6a). 13C NMR (300 MHz, [14] J. W. Steed, A. J. B. Smith, J. A. B. 1977.}
Acetone) δ 167.61C-7, 4.6-gallagyl, 158.32 C-7, 157.18 and 146.79 lactones, 96.27 (C-1), 74.57 (C-4), 73.14 (C-2), 74.57 (C-3), 70.92 (C-5), 64.56 (C-6).

Evaluation of antioxidant activities

2,2-diphenyl-1-picrylhydrazyl radical-scavenging activity
The antioxidant activities of the extracts and compounds have been measured in terms of hydrogen-donating or radical-scavenging ability using the stable radical DPPH. It determines the ability of the samples for trapping this unpaired electron to the disappearance of radical color.

The DPPH radical-scavenging activity was determined according to the method described by Hiraganahalli et al. with slight modifications. To a 250 μl, total reaction volume containing 20 μl of 10 mM phosphate-buffered saline pH 7.4/vehicle buffer/positive control (gallic acid)/test solutions of various concentrations, 230 μl of ABTS radical solution (0.238 mM) was added, mixed, and immediately read at 734 nm using microplate reader. To assess the ABTS radical-scavenging activity, the formula, absorbance of control − absorbance of test sample/absorbance control ×100 is used where absorbance of control is the absorbance of ABTS radical in methanol.

Statistical analysis
The results were analyzed using GraphPad Prism 5.0 (GraphPad Software, Inc., San Diego, CA). Each experiment was carried out in triplicates. Values are presented as mean ± standard deviation.

RESULTS AND DISCUSSION
The aqueous acetone extract of fruit peel of P. granatum afforded punicalagin, 2,3-(S)-hexahydroxydiphenoyl-D-glucose, and punicalin, which were identified by physical and spectral analysis. HPLC was

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Figure 1: Scheme of isolation process

Figure 2: Structure of the isolated compounds - punicalagin (1), 2,3-(S)-hexahydroxydiphenoyl-D-glucose (2), punicalin (3)
carried out for different extracts and isolated compounds to identify the presence of phytoconstituents in the extracts [Figure 3]. All isolated compounds and extracts were tested in vitro for their antioxidant activity, and the results for DPPH and ABTS assay were displayed in Figure 4.

In DPPH assay, the extracts and compounds were demonstrated a dose-dependent increase at concentrations ranging from 3.33–30 to 3.33–100 μg/ml, respectively. The percentage inhibition values showed the following order of radical-scavenging activity: aqueous acetone extract > methanol extract > water extract > ethyl acetate extract > chloroform extract. Among the compounds, 2,3-(S)-hexahydroxydiphenoyl-glucose showed significant antioxidant and radical quenching potential [Table 1].

The ABTS assay results have shown that the extracts and compounds displayed a dose-dependent activity with different concentrations (50, 100, and 200 μg/ml). Punicalin showed the significant scavenging activity when comparing with other isolated compounds [Table 2]. The order of ABTS radical-scavenging activity of all extracts was similar to that observed for DPPH. The extracts of lower polarity solvents, chloroform, and ethyl acetate showed lower antioxidant activity compared to polar solvents. The antioxidant activity shown by the polar solvent extracts may be due to the presence of highest total phenolic content.
Table 1: 2,2-diphenyl-1-picrylhydrazyl radical-scavenging activity of isolated compounds and different extracts of Punica granatum peel

| Sample name            | Percentage of inhibition                  |
|-----------------------|------------------------------------------|
|                       | 3 µg/ml | 10 µg/ml | 30 µg/ml | 100 µg/ml | 200 µg/ml |
| Punicalagin            | 26.45±0.55* | 65.49±0.53* | 94.21±0.29* | Not tested |
| 2,3-(S)-HHDP-glucose  | 28.97±0.43* | 91.31±0.25* | 93.83±0.82* | Not tested |
| Punicin                | 34.26±0.82* | 84.26±0.24* | 94.71±0.27* | Not tested |
| Chloroform extract     | 0.84±0.06  | 0.52±0.07  | 2.31±0.26  | 0.73±0.12  |
| Ethyl acetate extract  | 9.01±0.22  | 27.25±0.50* | 73.58±0.65* | 94.97±0.64* |
| Methanol extract       | 14.68±0.33 | 44.86±0.38* | 94.23±0.81* | 95.60±0.37* |
| Aqueous acetone extract| 34.91±1.0* | 87.63±0.48* | 94.65±0.23* | 94.86±0.41* |
| Water extract          | 6.96±0.21  | 42.32±0.15* | 92.54±0.28* | 94.36±0.89* |

The values are represented as mean±SD (n=3). The criterion for statistical significance was *P<0.05. HHDP: 2,3-(S)-hexahydroxydiphenoyl-D-glucose; SD: Standard deviation

Table 2: 2,2’-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid) radical-scavenging activity of isolated compounds and different extracts of Punica granatum peel

| Sample name            | Percentage inhibition                  |
|-----------------------|------------------------------------------|
|                       | 50 µg/ml | 100 µg/ml | 200 µg/ml |
| Punicalagin            | 29.85±0.26* | 64.36±0.44* | 98.41±0.06* |
| 2,3-(S)-HHDP-glucose  | 28.10±0.21* | 56.05±0.42* | 98.41±0.06* |
| Punicin                | 41.85±0.50* | 76.51±0.48* | 99.38±0.29* |
| Chloroform extract     | 0.21±0.06  | 2.05±0.80  | 1.18±0.39  |
| Ethyl acetate extract  | 11.59±0.50 | 18.00±0.92* | 30.67±0.63* |
| Methanol extract       | 11.90±0.23 | 22.72±0.35* | 44.62±0.38* |
| Aqueous acetone extract| 26.41±0.52* | 51.85±0.88* | 96.76±0.36* |
| Water extract          | 11.54±0.54 | 22.26±0.45* | 47.49±0.40* |

The values are represented as mean±SD (n=3). The criterion for statistical significance was *P<0.05. HHDP: 2,3-(S)-hexahydroxydiphenoyl-D-glucose; SD: Standard deviation

CONCLUSION

Pomegranate peel is a good source of phenolic compounds and has potent antioxidant activity. Here, the presence of antioxidant properties of three compounds punicalagin, 2,3-(S)-hexahydroxydiphenoyl-glucose, and punicin in the peel of pomegranate has been demonstrated. Further work is in progress to find out the nutritional and therapeutic properties.

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Conflicts of interest

There are no conflicts of interest.

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