CHEMICAL CONSTITUENTS AND ANTIOXIDANT ACTIVITY OF Salix tetrasperma ROXB

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ABSTRACT
Six (1-6) and two (7-8) compounds were obtained from ethyl acetate extract of S. tetrasperma Roxb bark and leaves, respectively. Structures of isolated compounds were determined by spectroscopic data, including $^1$H NMR, $^{13}$C NMR, and two dimensional NMR as β-sitosterol glucoside (1), 3,4-dihydroxybenzoic acid (2), 2-(hydroxymethyl)phenol (3), 1,3-dihydroxyphenol (4), 3-(hydroxymethyl)phenol (5), 4-methylbenzaldehyde (6), 1,2-dihydroxybenzene (7) and 3',4',5,7-tetrahydroxyflavone (8). Interestingly, compounds 2, 4, 5, 6, and 8 were reported for the first time isolated from this plant. The antioxidant activities of all crude extracts were evaluated by the diphenylpicrilhydrazyl (DPPH) method. Among all extracts, methanol extract of the bark has the highest antioxidant activity with an IC$_{50}$ value of 6.85 µg/mL. The activity of ethyl acetate extract of the root (IC$_{50}$ 19.53 µg/mL) was stronger than the bark (IC$_{50}$ 22.69 µg/mL).

Keywords: Salix tetrasperma Roxb, NMR, Antioxidant Activity, DPPH Method.

INTRODUCTION
Salix tetrasperma Roxb belongs to the Salicaceae family. This plant is commonly called “dalu-dalu” in West Sumatera, Indonesia and has been used as a traditional medicine to treat coughs and skin diseases as well as to reduce fever. The pharmacological activities of this plant showed that the bark extract of this plant possessed hypoglycemic activity, while the leaf extract showed antimicrobial, antipyretic, analgesic, and anti-inflammatory activities. The previous phytochemical work on this genus revealed that most species contain numerous phenolic compounds. According to our previous study, the polyphenolic compounds showed good biological activities. Salicin glycosides from S. glandulosa showed anti-neuroinflammatory activity. Recently the salicin derivatives from S. acmophylla were reported as cytotoxic and anti-inflammatory. Simple phenolic compounds from S. capensis bark had the antibacterial activity to P. aeruginos. Only a few phytochemical studies have been reported on S. tetrasperma Roxb. The phytochemical composition of Salix from different regions may vary, due to the environment of the growing plant. However, the information on chemical constituents from S. tetrasperma Roxb growing in Indonesia is still limited. Due to a large number of phenolic compounds that were reported from this genus, the authors are also interested to evaluate the antioxidant activity from various parts of this plant. Hence, this study aims to isolate secondary metabolite compounds from ethyl acetate extract of S. tetrasperma Roxb bark and leaves and to investigate the antioxidant activity of n-hexane, ethyl acetate, and methanol extracts various parts of S. tetrasperma Roxb.

EXPERIMENTAL
Material and Methods
All solvents were purchased from the suppliers with further purification before usage. Silica gel for column chromatography was performed on silica gel 60 (Merck). TLC plates pre-coated with silica gel 70 F$_{254}$ (60-200 mesh) were purchased from Wako Pure Chemical Industries, Japan. TLC spots were detected under the UV lamp (254 and 365 nm). $^1$H, $^{13}$C, HMHC, HMBC, and $^1$H-$^1$H COSY NMR spectra were recorded with JEOL JNM-ECS 400, 500, and 600 spectrometers using TMS as an internal standard. Two-dimensional $^1$H-$^1$H COSY, HMHC, and HMBC correlations were made by using standard pulse sequences.

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Plant Material
Leaves, root, and bark of *S. tetrasperma* Roxb were collected from the surrounding of Singkarak Lake, West Sumatera Province, Indonesia in May 2015. The plant was identified by a taxonomist at Herbarium of Andalus University (ANDA), Padang, Indonesia.

Extraction and Isolation
Each of the powdered samples (5 kg of leaves, 200 g of the root, and 11 kg of bark) was macerated in *n*-hexane for 3 days at room temperature and the process was repeated 4 times. All *n*-hexane filtrates of each part were concentrated by a rotary evaporator. The residue was immersed in ethyl acetate (EtOAc) and lastly followed in methanol (MeOH) in the same aforementioned process.

The crude EtOAc extract of the bark (100 g) was fractionated on silica gel 60, eluted with increasing polarity of solvents (100% *n*-hexane, dichloromethane (DCM), EtOAc until 100% MeOH) to afford nineteen fractions (A-S). Fraction R (12.22 g) was recrystallized with MeOH to obtain compound 1 (50 mg) as a white powder that turned into purple after treatment with 10% H₂SO₄ on the TLC plate. Fraction K (0.787 g) was purified on CC, eluted with a mixture of *n*-hexane/DCM (1:0→0:1, v/v), DCM/EtOAc (1:0→0:1, v/v) to yield nine fractions (K1-K9). Compound 2 (8 mg) was attained from fraction K4 as a yellow crystal. Fraction G (0.455 g) was separated on CC (DCM/EtOAc, 1:0→1:1, v/v) to give 16 fractions (G1-G16). Fraction G7 (50 mg) was purified on CC to give compound 3 (6 mg) as an orange crystal and compound 4 (4 mg) was acquired from fraction G14 as a white crystal. Fraction D (5.2 g) was separated into SiO₂ to yield five sub-fractions (D1-D5). Fraction D1 (1.04 g) was separated on sephadex (DCM/MeOH, 1:1, v/v) to give three fractions (D11-D13). Fraction D13 (0.450 g) was purified using CC (*n*-Hex/EtOAc, 4:1, v/v) to give compound 5 (10 mg) as an orange crystal. Fraction E (8.30 g) was separated on CC to give eight fractions (E1-E8). Fraction E2 (4.76 g) was separated on CC (DCM/EtOAc, 1:0→0:1, v/v) to obtain nine fractions (E21-E29). Fraction E24 (30 mg) was purified on sephadex by using MeOH to get compound 6 (3 mg) and was attained as a brownish crystal. The dried EtOAc extract of the leaves (60 g) was separated on silica gel with *n*-hexane/CHCl₃ (1:1, v/v), CHCl₃/MeOH (10:0→0:10, v/v) to give seven fractions (L1-L7). Fraction L5 (3 g) was chromatographed on silica gel to yield four sub-fractions (L51-L54). The fraction of L52 (1 g) was purified using silica gel (*n*-Hex/EtOAc, 4:1, v/v) to give compound 7 (70 mg) as a colorless crystal. Fraction L6 (5 g) was separated on silica gel (CHCl₃/EtOAc, EtOAc/MeOH, 10:0→0:10, v/v) to yield ten sub-fractions (L61-L610). Compound 7 was also obtained from fraction L62. The recrystallization of fraction L66 obtained compound 8 (40 mg).

Spectral Data

**β-Sitosterol Glucoside (1)**
H NMR (500 MHz, DMSO-d₆) δ ppm: 0.65 (3H, s, H-18), 0.81 (3H, d, J = 8 Hz, H-27), 0.80 (3H, d, J = 8 Hz, H-26), 0.83 (3H, s, H-19), 0.89 (3H, d, J = 6.5 Hz, H-21), 0.95 (3H, d, J = 8 Hz, H-29), 3.12 (1H, m, H-3), 3.05 (1H, d, J = 5.2 Hz, H-2', H-3'), 3.46 (1H, dd, J = 7.3 Hz, H-3'), 4.43 (1H, t, J = 5.2 Hz, H-1'), 4.87 (1H, t, J = 5.2 Hz, H-6'b), 4.90 (1H, dd, J = 4.5 Hz, H-6'a); and 5.38 (1H, brs, J = 4.5 Hz, H-6). C NMR (125 MHz, DMSO-d₆) δ ppm: 36.83 (C-1), 29.27 (C-2), 76.87 (C-3), 39.28 (C-4), 140.44 (C-5), 121.22 (C-6), 31.42 (C-7), 31.37 (C-8), 49.60 (C-9), 36.21 (C-10), 20.60 (C-11), 38.30 (C-12), 41.86 (C-13), 56.17 (C-14), 23.87 (C-15), 27.80 (C-16), 55.42 (C-17), 11.68 (C-18), 19.11 (C-19), 35.48 (C-20), 18.62 (C-21), 33.34 (C-22), 25.43 (C-23), 45.14 (C-24), 28.70 (C-25), 19.72 (C-26), 18.94 (C-27), 22.61 (C-28), 11.79 (C-29), 100.77 (C-1''), 73.47 (C-2''), 76.91 (C-3''), 70.11 (C-4''), 76.75 (C-5''), 61.10 (C-6'').

**3. 4-Dihydroxybenzoic Acid (2)**
H NMR (500 MHz, DMSO-d₆) δ ppm: 12.28 (brs), 9.62 (brs), 9.30 (brs), 7.33 (d, 1H, J = 2.1 Hz, H-2), 7.28 (dd, 1H, J = 8.2; 2.1 Hz, H-6), 6.77 (d, 1H, J = 8.2 Hz, H-5). C NMR (125 MHz, DMSO-d₆) δ ppm: 168.24 (C-7), 150.60 (C-4), 145.41 (C-3), 122.73 (C-6), 122.20 (C-11), 117.08 (C-2), 115.811 (C-5).

**2-(Hydroxymethyl) Phenol (3)**
H NMR (400 MHz, Acetone-d₆) δ ppm: 7.21 (d, 1H, J = 7.32 Hz, H-3), 7.07 (t, 1H, J = 8.24 Hz, H-5), 6.78 (t, 1H, J = 7.32; 8.24 Hz, H-4), 6.77 (d, 1H, J = 8.24 Hz, H-6), 4.71 (s, 2H, H-7). C NMR (100 MHz,
Acetone-$d_6$ δ ppm: 155.36 (C-1), 127.99 (C-3), 127.53 (C-5), 127.45 (C-2), 119.32 (C-4), 115.17 (C-6), 61.02 (C-7).

1, 3-Dihydroxyphenol (4)

H NMR (400 MHz, Acetone-$d_6$) δ ppm: 7.88 (dd, 1H, $J_1$ = 2.28; 1.84 Hz, H-2), 7.51 (td, 1H, $J_2$ = 7.76; 1.84 Hz, H-5), 6.91 (dd, 2H, $J_3$ = 0.92 Hz, H-4 and H-6). C NMR (100 MHz, Acetone-$d_6$) δ ppm: 135.9 (C-1 and C-3), 130.45 (C-5), 119.00 (C-4 and C-6), 117.00 (C-2).

3-(Hydroxymethyl) Phenol (5)

H NMR (400 MHz, CDCl$_3$) δ ppm: 7.21 (td, 1H, $J_1$ = 8; 0.92 Hz, H-5), 7.03 (dd, 1H, $J_2$ = 8; 1.36 Hz, H-6), 6.87 (dd, 1H, $J_3$ = 1.36; 0.92 Hz, H-4), 4.85 (s, 2H, H-7). C NMR (125 MHz, CDCl$_3$) δ ppm: 156.14 (C-1), 129.61 (C-3), 127.92 (C-5), 124.73 (C-4), 120.18 (C-6), 116.62 (C-2), 64.74 (C-7).

4-Methylbenzaldehyde (6)

H NMR (400 MHz, Acetone-$d_6$) δ ppm: 9.13 (brs), 7.87 (dd, 2H, $J_1$ = 8; 4 Hz, H-2 and H-6), 6.90 (dd, 2H, $J_2$ = 8; 4 Hz, H-3 and H-5), 2.46 (s, 3H, Me). C NMR (100 MHz, Acetone-$d_6$) δ ppm: 195.73 (C-7), 161.86 (C-4), 130.79 (C-2 and C-6), 129.66 (C-1), 115.19 (C-3 and C-5), 28.90 (Me).

1, 2-Dihydroxybenzene (7)

H NMR (400 MHz, Acetone-$d_6$) δ ppm: 6.67 (m, 2H, H-3 and H-6), 6.82 (m, 2H, H-4 and H-5). C NMR (125 MHz, Acetone-$d_6$) δ ppm: 145.14 (C-1 and C-2), 119.97 (C-3 and C-6), 115.38 (C-4 and C-5).

3', 4', 5, 7-Tetrahydroxyflavone (8)

H NMR (600 MHz, Methanol-$d_3$) δ ppm: 7.38 (d, 1H, $J_1$ = 2.76 Hz, H-2'), 7.37 (d, 1H, $J_2$ = 8.94 Hz, H-6'), 6.90 (d, 1H, $J_3$ = 8.94 Hz, H-5'), 6.53 (s, 1H, H-3), 6.43 (d, 1H, $J_4$ = 2.04 Hz, H-8), 6.20 (d, 1H, $J_5$ = 2.04 Hz, H-6). C NMR (150 MHz, Methanol-$d_3$) δ ppm: 182.52 (C-4), 165.00 (C-7), 164.65 (C-2), 161.87 (C-5), 158.06 (C-9), 149.64 (C-4'), 145.70 (C-3'), 122.33 (C-1'), 118.94 (C-6'), 115.42 (C-5'), 112.80 (C-2'), 103.96 (C-10), 102.51 (C-3), 98.75 (C-6), 93.63 (C-8).

Antioxidant Activity

The antioxidant activities of various $S$. tetrasperma Roxb extracts were determined by using DPPH radical scavenged method$^{12}$ with slight modification. 3 mL of each solution [in various concentrations] of tested samples (n-hexane, EtOAc, and MeOH extracts of the leaves, roots, and bark) was poured into 1 mL of DPPH solution [0.1 mmol/L]. The mixture was incubated for 30 minutes at room temperature in the dark place and then recorded by UV-spectrophotometer at 517 nm. As a comparison, the ascorbic acid and methanol were used as a standard and a blank, respectively. The antioxidant activity was calculated based on the percentage of DPPH radical scavenged (% Inhibition) using the following equation:

$$\%\text{Inhibition} = \left(\frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}}\right) \times 100$$

Where $A_{\text{control}}$ is the absorbance of control containing all reagents that exclude the sample, and $A_{\text{sample}}$ is the absorbance of the sample. The measurements were taken in triplicate. The antioxidant results were expressed as the IC$_{50}$ value ± standard deviation (SD).

RESULTS AND DISCUSSION

Characterization of Isolated Compounds

After separation by chromatography technique, six (1-6) and two (7-8) compounds were isolated from EtOAc extract of $S$. tetrasperma Roxb bark and leaves, respectively. The structures of isolated compounds were displayed in Fig.-1.

Compound 1 was acquired as a white powder (50 mg). The H NMR spectrum of 1 showed the presence of a broad singlet signal at $\delta_{\text{H}}$ 5.38 ppm characterized as an olefinic proton (H-6). While one proton as a
multiplet at $\delta_{\text{H}}$ 3.12 ppm was assigned as an oxymethine proton (H-3). A steroidal nucleus was assigned by the presence of two protons at $\delta_{\text{H}}$ 3.12 (H-3) and 5.38 (H-6).

Furthermore, six methyl protons appeared in the H NMR spectrum as singlet protons at $\delta_{\text{H}}$ 0.65 (H-18) and 0.83 (H-19), doublet protons at $\delta_{\text{H}}$ 0.80 (H-26), 0.81 (H-27), 0.89 (H-21), and 0.95 (H-29) respectively. On the other hand, the sugar moiety protons resonated at $\delta_{\text{H}}$ 3.05-4.90 ppm, while the proton at $\delta_{\text{H}}$ 4.43 ppm indicated an anomeric proton (H-1'). The C NMR spectrum of 1 appeared 35 carbon signals including 29 signals of a steroidal compound and 6 signals of glucose moiety in its structure. The signals at $\delta_{\text{C}}$ 140.44 and 121.22 ppm showed the occurrence of olefinic carbons at C-5 and C-6, respectively. Meanwhile, the signal at $\delta_{\text{C}}$ 76.87 ppm indicated oxymethine carbon at C-3. Moreover, six methyl carbon signals appeared at $\delta_{\text{C}}$ 11.68 (C-18), 11.79 (C-29), 18.62 (C-21), 18.94 (C-27), 19.11 (C-19), and 19.72 (C-26). The remaining six signals at $\delta_{\text{C}}$ 100.77 (C-1'), 73.47 (C-2'), 76.91 (C-3'), 70.11 (C-4'), 76.75 (C-5') and 61.10 (C-6') were assigned for sugar moiety. Based on H and C NMR spectral data, and compared to related literature, compound 1 was identified as $\beta$-sitosterol glucoside.\textsuperscript{13-15}

Compound 2 was obtained as a yellow crystal (8 mg). The H NMR spectrum of 2 showed three aromatic protons at $\delta_{\text{H}}$ 7.33 (d, 1H, $J = 2.1$ Hz, H-2), 7.28 (dd, 1H, $J = 8.2$; 2.1 Hz, H-6), and 6.77 (d, 1H, $J = 8.2$ Hz, H-5), while six aromatic signals at $\delta_{\text{C}}$ 115.81, 150.60, 145.41, 122.73, 122.20, 117.08 ppm, and one carbonyl signal at $\delta_{\text{C}}$ 168.24 ppm appeared in C NMR spectrum. In $^1$H-$^1$H COSY spectrum, the proton at $\delta_{\text{H}}$ 7.28 ppm exhibited meta-coupling with the proton at $\delta_{\text{H}}$ 7.33 ppm ($J = 2.1$ Hz) and it also had ortho-coupling with the proton at $\delta_{\text{H}}$ 6.77 ppm ($J = 8.2$ Hz), that assigned trisubstitution at 1, 3 and 4 positions in the aromatic ring. A broad singlet signal in the most downfield region ($\delta_{\text{H}}$ 12.28 ppm) assigned the occurrence of carboxylic acid bound to the aromatic ring of 2. By H and C NMR analyses and comparison with the previously reported data, the chemical structure of 2 was determined as 3,4-dihydroxybenzoic acid or protocatechuic acid.\textsuperscript{16-18}

Compound 3 was isolated as an orange crystal (6 mg). The H NMR of 3 displayed four aromatic protons and an oxidized methylene proton ($\delta_{\text{H}}$ 4.71 ppm). The most downfield proton at $\delta_{\text{H}}$ 7.21 ppm revealed ortho-coupling with the proton at $\delta_{\text{H}}$ 6.78 ppm ($J = 7.32$ Hz), while the proton at $\delta_{\text{H}}$ 7.07 ppm as a triplet

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Fig.-1: Isolated Compounds from S. tetrasperma Roxb Bark; $\beta$-Sitosterol Glucoside (1), 3,4-Dihydroxybenzoic Acid (2), 2-(Hydroxymethyl) Phenol (3), 3-(Hydroxymethyl) Phenol (5), 4-Methylbenzaldehyde (6), and from the Leaves; 1,2-Dihydroxybenzene (7) and 3',4',5,7-Tetrahydroxyflavone (8).
Salix tetrasperma bark, root, and leaves as 6.85 ± 0.05; 16.93 ± 0.12; and 27.43 ± 0.44 µg/mL, respectively. The activity of extract of the root (Table-1). All MeOH extracts possessed strong antioxidant activity with IC₅₀ value of bark, root, and leaves as 6.85 ± 0.05; 16.93 ± 0.12; and 27.43 ± 0.44 µg/mL, respectively. The activity of different extracts was in the MeOH extract of the bark, while the minimum was found in the n-hexane extract of the root (Table-1). All MeOH extracts possessed strong antioxidant activity with IC₅₀ value of bark, root, and leaves as 6.85 ± 0.05; 16.93 ± 0.12; and 27.43 ± 0.44 µg/mL, respectively. The activity of

Antioxidant Activity

The DPPH radical scavenging results of *S. tetrasperma* Roxb barks, root, and leaves extracts were assayed as described in Materials and Methods. The highest antioxidant scavenging among the nine different extracts was in the MeOH extract of the bark, while the minimum was found in the n-hexane extract of the root (Table-1). All MeOH extracts possessed strong antioxidant activity with IC₅₀ value of bark, root, and leaves as 6.85 ± 0.05; 16.93 ± 0.12; and 27.43 ± 0.44 µg/mL, respectively. The activity of

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EtOAc extract of the root (IC$_{50}$ 19.53 ± 0.22 µg/mL) was stronger than that of the bark (IC$_{50}$ 22.69 ± 0.29 µg/mL), whereas the EtOAc extract of the leaves was not active (IC$_{50}$ 142.18 ± 1.29 µg/mL) and also all parts of n-hexane extracts. Compared to the positive control, all tested samples showed lower scavenging activity than ascorbic acid (IC$_{50}$ 2.19 ± 0.04 µg/mL).

Table 1: Antioxidant Activity of *S. tetrasperma* Roxb Extracts (mean ± SD), *n* = 3

| Extract        | Part  | IC$_{50}$ (µg/mL) ± SD |
|----------------|-------|------------------------|
| n-Hexane       | Root  | 916.35 ± 13.15         |
|                | Bark  | 487.36 ± 2.78          |
| Ethyl acetate  | Root  | 19.53 ± 0.22           |
|                | Bark  | 22.69 ± 0.29           |
|                | Leaves| 142.18 ± 1.29          |
| Methanol       | Root  | 16.93 ± 0.12           |
|                | Bark  | 6.85 ± 0.05            |
|                | Leaves| 27.43 ± 0.44           |
| Ascorbic acid  | -     | 2.19 ± 0.04            |

The number of electrons taken up is very important for antioxidant scavenging activity. This is due to the ability of hydrogen donors from polyphenol compounds and also the correlation with the total flavonoid content contained in the extract. Our phytochemical investigation showed that the presence of phenolic and flavonoid in MeOH and EtOAc extract of the bark and leaves of *S. tetrasperma* Roxb might contribute to the high antioxidant activity. Thus, this plant can be considered as a good natural antioxidant source.

**CONCLUSION**

The chemical constituents of *S. tetrasperma* Roxb were evaluated by isolating six compounds from EtOAc extract the bark such as β-sitosterol glucoside (1), 3,4-dihydroxybenzoic acid (2), 2-(hydroxymethyl)phenol (3), 1,3-dihydroxyphenol (4), 3-(hydroxymethyl)phenol (5), 4-methylbenzaldehyde (6) and two compounds from EtOAc extract of *S. tetrasperma* Roxb leaves as 1,2-dihydroxybenzene (7) and 3',4',5,7-tetrahydroxyflavone (8). MeOH extract from the bark, root, and leaves of *S. tetrasperma* Roxb had a strong antioxidant activity with IC$_{50}$ value of 6.85 ± 0.05; 16.93 ± 0.12; and 27.43 ± 0.44 µg/mL, respectively.

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