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Saponins from the Leaves of *Panax vietnamensis* Ha et Grushv. (Vietnamese ginseng) and Their Inhibitory Activities on α-Glucosidase

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Abstract – Vietnam boasts a rich and diverse flora, with many endemic species. Among them, Ngoc Linh ginseng (Vietnamese ginseng; scientific name: *Panax vietnamensis* Ha et Grushv.), a high-value endemic ginseng species, has been recognized as a national treasure. While numerous studies have been conducted on its rhizomes and roots, research on its leaves remains limited. In this study, six compounds (**1**–**6**) were isolated from the methanol extract of the leaves of *P. vietnamensis*. Their structures were elucidated using ESI-MS, 1D and 2D NMR spectroscopic methods, and comparisons with known literature data. The identified compounds are: 12β,20(*R*),25-trihydroxydammara-3-*O*-β-D-glucopyranoside (**1**); 12β,20(*R*),25-trihydroxydammara-3-*O*-β-D-glucopyranosyl-(1→2)-β-D-glucopyranoside (**2**); notoginsenoside SFt1 (**3**); ginsenoside Rh2 (**4**); ginsenoside Rg3 (**5**) and notoginsenoside L1 (**6**). Except for compound **3**, which was isolated from the leaves for the first time, the other five compounds are reported from this species for the first time. The α-glucosidase inhibition assay of the pure isolated compounds revealed that compounds **1**, **4**, and **6** exhibited significant activities, with IC_{50} values of 133.5, 105.5, and 14.9, respectively. For comparison, the positive control, acarbose, had an IC_{50} value of 138.2 μM.
Keywords – Vietnamese ginseng, *Panax vietnamensis*, Leaves, Saponin, Protopanaxadiol, Hexanordammarane

Introduction

In 1973, a new species of *Panax* was identified at an altitude of 1800 meters in the Ngoc Linh mountain range, located in Kon Tum province. By 1985, this species received the official name *Panax vietnamensis* Ha et Grushv., a member of the Araliaceae family.[1–3] Known as Vietnamese ginseng, *P. vietnamensis* is notably rich in saponins, which are present in significant amounts throughout its rhizomes, roots, and leaves. In fact, this species has been found to have a higher concentration of saponins compared to other *Panax* species like *P. ginseng* (Korean ginseng), *P. quinquefolium* (American ginseng), and *P. notoginseng* (Chinese ginseng). It also contains a distinctive group of ocotillol-type saponins, which are absent in Korean ginseng. As of now, 63 saponin compounds[1,4–9] and 24 non-saponin compounds have been isolated from the plant's rhizomes, roots, and leaves.[10–14]

Minority ethnic groups such as the Xe Đang, Ba Na, Gia Rai, and Ta Oi have been using Ngoc Linh ginseng for a long time. Ngoc Linh ginseng is known for its many benefits, treating various ailments, particularly those related to physical performance. Clinical research has demonstrated its extensive bioactivities, including enhancing health, combating fatigue, reducing stress, supporting the treatment of chronic diseases, improving immunity, and exhibiting antioxidant, antibacterial, anti-stress, and anti-diabetic properties.[8,15–17] While many studies have focused on its rhizomes and roots, fewer investigations have been done on the leaves.

In this study, six compounds were extracted from the leaves of Vietnamese ginseng and identified as 12β,20(*R*),25-trihydroxydammara-3-*O*-β-D-glucopyranoside (**1**); 12β,20(*R*),25-trihydroxydammara-3-*O*-β-D-glucopyranosyl-(1→2)-β-D-glucopyranoside (**2**); notoginsenosides SFt1 (**3**); ginsenoside Rh2 (**4**); ginsenoside Rg3 (**5**); and notoginsenoside L1 (**6**). The α-glucosidase inhibitory activity has been tested on the isolated compounds.

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Experimental

General experimental procedures – All solvents, including *n*-hexane, chloroform, ethyl acetate, isopropanol, and methanol, were products of Topsol (India) and LabScan (Sweden). Bruker Ultrashield 500 Plus (500 MHz, Germany) was used for the NMR data. MS was measured using the Bruker micrOTOF QII (Germany). Column chromatography (CC) was carried out with silica gel (Merck) type 0.063-0.200 mm ASTM, silica gel (Himedia) type 37-63 mm GRM7484-500G, and LiChroprepVR RP-18, 40–63 μm (Merck KGaA, Darmstadt, Germany). Thin-layer chromatography (TLC) was conducted on precoated Kieselgel 60 F-254 or RP-18 plates (Merck KGaA, Darmstadt, Germany).

Plant materials – In October 2019, the leaves of *Panax vietnamensis*, commonly known as Vietnamese ginseng, were harvested from Kon Tum province, Vietnam. A reference sample, identified as PV 2019, has been preserved in the Department of Organic Chemistry, Faculty of Chemistry, at VNUHCM–University of Science.

Extraction and isolation – The leaves of Vietnamese ginseng (3957 g) were pulverized into a fine powder and sequentially extracted four times under reflux, each for three hours, using 20 L of each solvent in the following order: *n*-hexane (HE), chloroform (CF), ethyl acetate (EA), and methanol (ME). This process yielded four extracts: HE (97.50 g), CF (63.32 g), EA (102.85 g), and ME (853.02 g). The ME extract (853.02 g) was then subjected to silica gel column chromatography, eluted with a gradient of EA and ME (from 90:10 to 0:100), resulting in five primary fractions: ME1 (33.32 g), ME2 (72.61 g), ME3 (70.86 g), ME4 (125.26 g), and ME5 (545.03 g).

Fraction ME4 (125.26 g) was further chromatographed on silica gel, using a gradient of EA and ME (from 100:0 to 0:100), yielding six subfractions (ME4.1 through ME4.6). Fraction ME4.2 (51.47 g) underwent additional silica gel chromatography with a gradient of EA and ME (from 95:5 to 50:50), producing five subfractions (ME4.2.1 through ME4.2.5). Fraction ME4.2.4 (6.78 g) was further processed on a C18 RP column, eluted with ME and W (water) (60:40), yielding six fractions (ME4.2.4.1–ME4.2.4.6). ME4.2.4.4 (251.5 mg) was subjected to silica gel chromatography with a gradient of EA and ME (90:10), resulting in the isolation of compound **1** (8.0 mg). Similarly, ME4.2.4.6 (1.21 g) was chromatographed on a C18 RP column with a ME-W mixture (30:70), yielding compound **2** (15.1 mg).

Fraction ME5 (545.03 g) was processed via silica gel chromatography, eluted with a gradient of EA and ME (from 100:0 to 0:100), resulting in eight fractions (ME5.1 through ME5.8). ME5.2 (72.61 g) was further separated by silica gel chromatography, using a gradient of EA-ME (from 90:10 to 0:100), producing eight subfractions (ME5.2.1 through ME5.2.8). ME5.2.4 (14.80 g) was chromatographed using an EA-ME gradient (from 90:10 to 50:50), generating additional fractions (ME5.2.1 through ME5.2.8). Fraction ME5.2.2 (6.29 g) was further processed with silica gel chromatography, using a CF-ME gradient (from 95:5 to 20:80), yielding five fractions (ME5.2.2.1–ME5.2.2.5). ME5.2.2.4 (272.5 mg) was separated on a C18 RP column, eluted with ME and W (5:95), yielding compound **3** (9.2 mg). ME5.2.2.5 (840.2 mg) was further processed on silica gel chromatography with a CF-ME-W mixture (90:9.8:0.2), resulting in three fractions (ME5.2.2.5.1–ME5.2.2.5.3). ME5.2.2.5.3 was then chromatographed on a C18 RP column with ME-W (70:30), yielding compound **6** (5.9 mg).

Finally, ME5.4 (2.56 g) was subjected to silica gel chromatography, using a CF-ME gradient (from 90:10 to 0:100), yielding six fractions (ME5.4.1–ME5.4.6). ME5.4.2 (350 mg) was further processed on a C18 RP column, eluted with a solvent mixture of AC (acetone), ME, W, and IP (isopropanol) (20:50:20:10), yielding compound **5** (18.8 mg). ME5.4.5 (256 mg) was also chromatographed on a C18 RP column, using the same solvent mixture, yielding compound **4** (9.0 mg).

12*β*,20(*R*),25-Trihydroxydammara-3-*O*-*β*-D-glucopyranoside (1) – White amorphous powder; ^{1}H-NMR (C_5D_5N, 500 MHz): δ 0.86 (3H, s, CH_3-18), 0.99 (3H, s, CH_3-30), 1.04 (3H, s, CH_3-29), 1.05 (3H, s, CH_3-19), 1.35 (3H, s, CH_3-28), 1.44 (3H, s, CH_3-21), 1.45 (6H, s, CH_3-26, CH_3-27), 3.41 (1H, dd, J = 11.8, 4.5 Hz, H-3), 4.98 (1H, d, J = 7.8 Hz, H-1′), 4.04 (1H, m, H-2′), 4.28 (1H, t, J = 8.8 Hz, H-3′), 4.23 (1H, t, J = 9.1 Hz, H-4′), 3.96 (1H, tdd, J = 10.3, 5.1, 1.9 Hz, H-5′), 4.62 (2H, dd, J = 11.7, 1.9 Hz, H-6′a), 4.42 (1H, dt, J = 11.1, 5.0 Hz, H-6′b); ^{13}C-NMR (C_5D_5N, 125 MHz): δ 39.4 (C-1), 26.9 (C-2), 89.0 (C-3), 39.9 (C-4), 56.6 (C-5), 18.6 (C-6), 35.4 (C-7), 40.2 (C-8), 50.6 (C-9), 37.2 (C-10), 32.2 (C-11), 71.0 (C-12), 49.5 (C-13), 51.9 (C-14), 31.6 (C-15), 26.9 (C-16), 51.0 (C-17), 16.9 (C-18), 16.0 (C-19), 73.5 (C-20), 23.0 (C-21), 44.2 (C-22), 18.9 (C-23), 45.8 (C-24), 69.9 (C-25), 30.3 (C-26), 30.1 (C-27), 28.3 (C-28), 16.5 (C-29), 17.5 (C-30), 107.1 (C-1′), 76.0 (C-2′), 78.9 (C-3′), 72.1 (C-4′), 78.5 (C-5′), 63.3 (C-6′).

12*β*,20(*R*),25-Trihydroxydammara-3-*O*-*β*-D-glucopyranosyl-(1→2)-*β*-D-glucopyranoside (2) – White amorphous powder; ^{1}H-NMR (C_5D_5N, 500 MHz): δ 0.86 (3H, s, CH_3-18), 0.98 (3H, s, CH_3-30), 1.14 (3H, s, CH_3-29), 1.05 (3H, s, CH_3-19), 1.33 (3H, s, CH_3-28), 1.43 (3H, s, CH_3-21), 1.45 (6H, s, CH_3-26, CH_3-27), 3.31 (1H, dd, J = 11.8, 4.5 Hz,

H-3), 4.98 (1H, d, J = 7.8 Hz, H-1′), 5.39 (1H, d, J = 7.7 Hz, H-1″); ^{13}C-NMR (C_5D_5N, 125 MHz): δ 39.5 (C-1), 27.0 (C-2), 89.3 (C-3), 40.0 (C-4), 56.7 (C-5), 18.8 (C-6), 35.5 (C-7), 40.4 (C-8), 50.7 (C-9), 37.3 (C-10), 32.4 (C-11), 71.2 (C-12), 49.6 (C-13), 52.1 (C-14), 31.8 (C-15), 27.1 (C-16), 51.1 (C-17), 16.2 (C-18), 16.7 (C-19), 73.7 (C-20), 23.1 (C-21), 44.4 (C-22), 19.0 (C-23), 45.9 (C-24), 70.1 (C-25), 30.2 (C-26), 30.5 (C-27), 28.4 (C-28), 16.9 (C-29), 17.7 (C-30), 105.4 (C-1′), 83.7 (C-2′), 78.3 (C-3′), 72.1 (C-4′), 78.4 (C-5′), 63.2 (C-6′), 106.2 (C-1″), 77.4 (C-2″), 78.7 (C-3″), 72.0 (C-4″), 78.5 (C-5″), 63.1 (C-6″).

Notoginsenosides SFt1 (3) – White amorphous powder; ^{1}H-NMR (C_5D_5N, 500 MHz): δ 0.82 (3H, s, CH_3-19), 0.99 (6H, s, CH_3-18, CH_3-30), 1.02 (3H, s, CH_3-29), 1.34 (3H, s, CH_3-28), 1.47 (3H, s, CH_3-21), 1.92 (3H, s, H-26), 4.95 (1H, brs, H-26a), 5.28 (1H, brs, H-26b), 4.97 (1H, d, J = 7.8 Hz, H-1′), 4.06 (1H, t, J = 8.3 Hz, H-2′), 4.03 (1H, m, H-3′), 3.95 (1H, td, J = 10.1, 5.1 Hz, H-4′), 4.25 (1H, t, J = 9.0 Hz, H-5′), 4.61 (1H, dd, J = 11.7, 2.5 Hz, H-6′a), 4.43 (1H, dd, J = 11.5, 5.4 Hz, H-6′b), 3.41 (1H, dd, J = 11.8, 4.4 Hz, H-3), 4.28 (1H, t, J = 8.8 Hz, H-12), 3.41 (1H, dd, J = 11.8, 4.4 Hz, H-3); ^{13}C-NMR (C_5D_5N, 125 MHz): 39.2 (C-1), 26.8 (C-2), 88.9 (C-3), 39.8 (C-4), 56.5 (C-5), 18.5 (C-6), 35.3 (C-7), 40.1 (C-8), 50.5 (C-9), 37.1 (C-10), 32.3 (C-11), 72.0 (C-12), 48.7 (C-13), 51.8 (C-14), 32.2 (C-15), 27.0 (C-16), 54.9 (C-17), 16.4 (C-18), 16.9 (C-19), 73.2 (C-20), 27.5 (C-21), 31.5 (C-22), 30.7 (C-23), 76.1 (C-24), 150.0 (C-25), 18.5 (C-26), 109.9 (C-27), 28.2 (C-28), 15.9 (C-29), 17.2 (C-30), 107.0 (C-1′), 75.9 (C-2′), 78.8 (C-3′), 71.1 (C-4′), 78.4 (C-5′), 63.2 (C-6′).

Ginsenoside Rh2 (4) – White amorphous powder; ESI-MS m/z 644.79 $[M–H+Na]^+$ (calcd. for $[C_{36}H_{61}O_8+Na]^+$, 644.43); ^{1}H-NMR (CD_3OD, 500 MHz): δ 0.91 (3H, s, CH_3-29), 0.98 (3H, s, CH_3-30), 0.99 (3H, s, CH_3-19), 1.07 (3H, s, CH_3-18), 1.11 (3H, s, H-28), 1.21 (3H, s, H-21), 1.68 (3H, s, H-27), 1.75 (3H, s, H-26), 4.38 (1H, d, J = 7.8 Hz, H-1′), 5.20 (1H, m, J = 6.9 Hz, H-24), 3.24 (1H, m, H-3); ^{13}C-NMR (CD_3OD, 125 MHz): δ 40.3 (C-1), 27.2 (C-2), 90.6 (C-3), 40.2 (C-4), 57.6 (C-5), 19.3 (C-6), 36.0 (C-7), 40.1 (C-8), 51.4 (C-9), 38.0 (C-10), 32.0 (C-11), 72.2 (C-12), 49.5 (C-13), 52.6 (C-14), 32.0 (C-15), 27.4 (C-16), 55.1 (C-17), 17.1 (C-18), 15.8 (C-19), 72.9 (C-20), 27.0 (C-21), 35.8 (C-22), 22.9 (C-23), 126.3 (C-24), 25.8 (C-25), 17.6 (C-26), 28.1 (C-27), 16.7 (C-28), 130.7 (C-29), 17.0 (C-30), 106.9 (C-1′), 75.7 (C-2′), 78.7 (C-3’), 71.8 (C-4′), 78.3 (C-5′), 63.0 (C-6′).

Ginsenoside Rg3 (5) – White amorphous powder; ESI-MS m/z 807.11 $[M+Na]^+$ (calcd. for $[C_{42}H_{72}O_{13}+Na]^+$, 807.48); ^{1}H-NMR ($CD_3OD$, 500 MHz): δ 0.86 (3H, s, CH_3-29), 0.93 (3H, s, CH_3-30), 1.02 (3H, s, CH_3-18), 1.05 (3H, s, CH_3-28), 1.35 (3H, s, CH_3-21), 1.63 (3H, s, CH_3-27), 1.69 (3H, s, CH_3-26), 4.65 (1H, d, J = 7.8 Hz, H-1″); ^{13}C-NMR (CD_3OD, 125 MHz): δ 36.7 (C-1), 27.2 (C-2), 90.6 (C-3), 37.9 (C-4), 57.6 (C-5), 19.3 (C-6), 35.9 (C-7), 40.2 (C-8), 51.1 (C-9), 40.4 (C-10), 31.7 (C-11), 71.2 (C-12), 49.8 (C-13), 52.5 (C-14), 31.0 (C-15), 27.2 (C-16), 53.2 (C-17), 17.2 (C-18), 16.8 (C-19), 75.7 (C-20), 22.9 (C-21), 41.0 (C-22), 24.2 (C-23), 125.9 (C-24), 132.3 (C-25), 25.9 (C-26), 17.9 (C-27), 28.4 (C-28), 16.3 (C-29), 16.8 (C-30), 106.7 (C-1′), 78.3 (C-2′), 75.7 (C-3′), 71.9 (C-4′), 77.9 (C-5′), 62.8 (C-6′), 98.3 (C-1″), 75.4 (C-2″), 78.3 (C-3″), 71.7 (C-4″), 77.7 (C-5″), 62.6 (C-6″).

Notoginsenoside L11 (6) – White amorphous powder; ^{1}H-NMR (C_5D_5N, 500 MHz): δ 0.79 (3H, s, CH_3-19), 0.94 (3H, s, CH_3-30), 0.98 (3H, s, CH_3-18), 1.12 (3H, s, CH_3-29), 1.31 (3H, s, H-28), 2.42 (3H, s, H-21), 2.42 (3H, s, H-21) 4.95 (1H, d, J = 7.6 Hz) (H-1'), 5.40 (1H, d, J = 7.6 Hz, H-1"); ^{13}C-NMR (C_5D_5N, 125 MHz): δ 40.0 (C-1), 27.0 (C-2), 89.2 (C-3), 40.0 (C-4), 56.7 (C-5), 18.7 (C-6), 35.9 (C-7), 40.5 (C-8), 51.3 (C-9), 37.3 (C-10), 33.2 (C-11), 71.9 (C-12), 55.1 (C-13), 51.8 (C-14), 33.2 (C-15), 27.9 (C-16), 53.1 (C-17), 16.0 (C-18), 16.8 (C-19), 213.7 (C-20), 30.8 (C-21), 28.4 (C-28), 16.9 (C-29), 17.3 (C-30), 105.4 (C-1′), 83.7 (C-2′), 78.7 (C-3′), 72.0 (C-4′), 78.5 (C-5′), 63.2 (C-6′), 106.3 (C-1″), 77.4 (C-2″), 78.7 (C-3″), 72.0 (C-4″), 78.5 (C-5″), 63.2 (C-6″).

Bioassay – The evaluation of α-glucosidase inhibitory activity followed a modified method based on Kim et al.,[18] with acarbose as the standard reference. The assay consisted of mixing 25 µL of 3 mM p-nitrophenyl-α-D-glucopyranoside, 25 µL of α-glucosidase (0.2 U/mL), and 625 µL of the sample dissolved in 0.01 M phosphate buffer (pH 7.0). The reaction was allowed to proceed for 30 minutes at 37°C and was stopped by adding 375 µL of 0.1 M sodium carbonate (Na_2CO_3). The absorbance at 401 nm was measured to monitor enzyme activity. One unit of enzyme activity was defined as the amount required to liberate 1.0 µM of p-nitrophenol per minute. The IC_{50} value, representing the concentration of inhibitor required to suppress 50% of the enzyme's activity, was calculated.

Results and Discussion

By employing silica gel column chromatography, the chemical analysis of the methanol extract from the leaves of *P. vietnamensis* resulted in the successful isolation of six compounds. The chemical structures of these compounds were elucidated using advanced spectroscopic techniques, including ESI-MS and 1D/2D NMR. Their spectral data

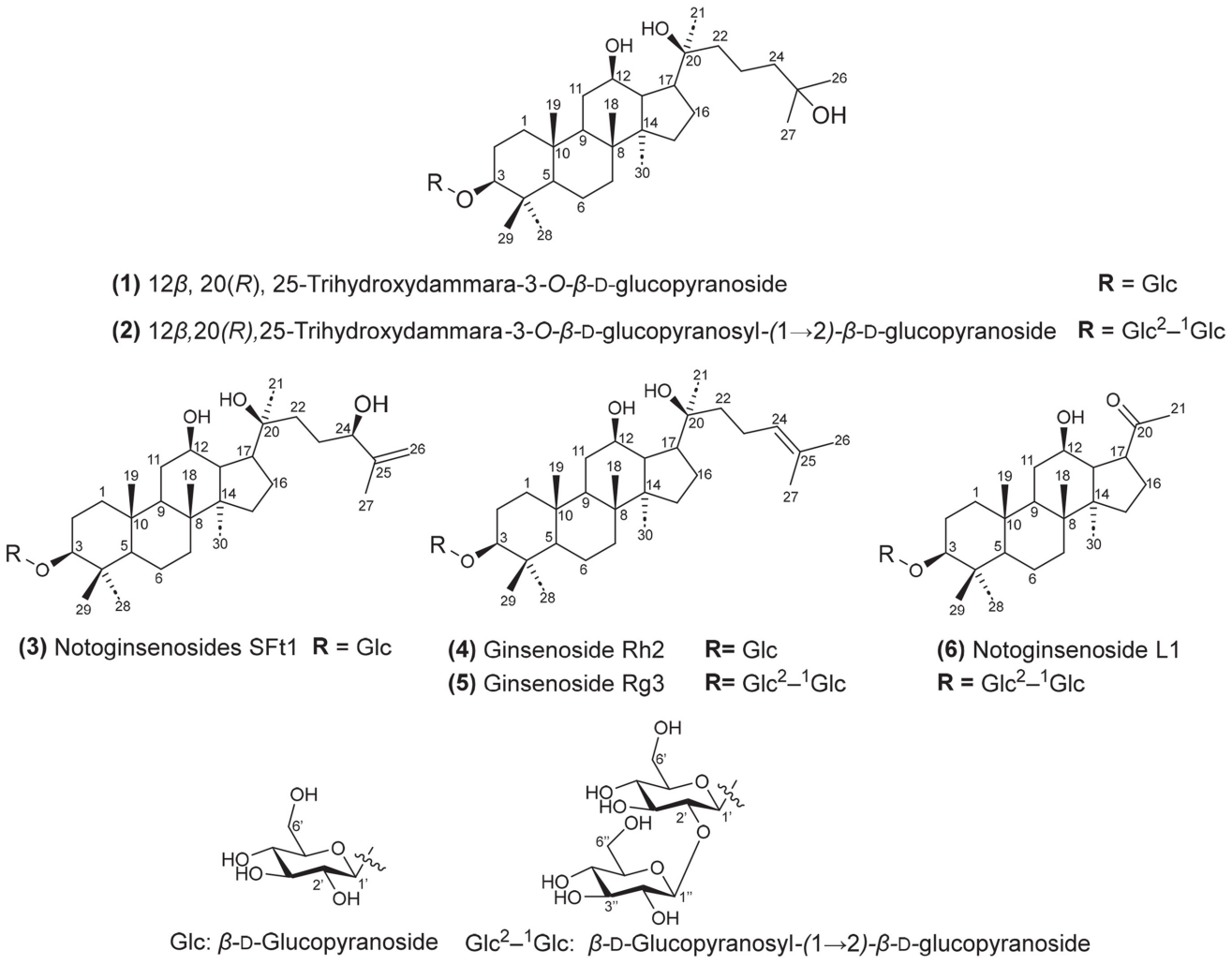

Fig. 1. Structures of six saponins from the leaves of *Panax vietnamensis*.

were then compared with existing literature to validate their identities (Fig. 1). Compounds **1**–**6** were identified as: 12*β*,20(*R*),25-trihydroxydammara-3-*O*-*β*-D-glucopyranoside (**1**);[19] 12*β*,20(*R*),25-trihydroxydammara-3-*O*-*β*-D-glucopyranosyl-(1→2)-*β*-D-glucopyranoside (**2**);[20] notoginsenosides SFt1 (**3**);[21] ginsenoside Rh2 (**4**);[22] ginsenoside Rg3 (**5**)[23] and notoginsenoside L1 (**6**).[24] All six compounds were isolated for the first time in *P. vietnamensis*.

Compound **1** (8.0 mg): white amorphous powder, highly soluble in pyridine. The ^{1}H NMR spectrum showed signals of eight methyl groups [δ_H 0.86 (3H, s, CH_3-18), 0.99 (3H, s, CH_3-30), 1.04 (3H, s, CH_3-29), 1.05 (3H, s, CH_3-19), 1.35 (3H, s, CH_3-28), 1.44 (3H, s, CH_3-21), 1.45 (6H, s, CH_3-26 and CH_3-27)], and one anomeric proton [δ_H 4.98 (1H, d, J = 7.8 Hz, H-1′)] of *β*-glucose sugar. The ^{13}C-NMR spectrum showed thirty-six signals with an anomeric carbon [δ_C 107.8 (C-1′)], five oxygenated carbons of *β*-glucose sugar [(δ_C 76.0 (C-2′), 78.9(C-3′), 72.1 (C-4′), 78.5 (C-5′), 63.3 (C-6′)], four oxygenated carbons of the aglycon part [(δ_C 89.0 (C-3), 71.0 (C-12), 73.5 (C-20), 69.9 (C-25)] and twenty-six signals in the high-field zone (10−55 ppm). The specific signals in the ^{1}H-NMR and ^{13}C-NMR spectra show that compound **1** belongs to the protopanaxadiol dammarane group and has a *β*-glucose moiety in its structure. HMBC cross peak of the anomeric proton at δ_H 4.98 (1H, d, J = 7.8 Hz, H-1′) with carbon signal at δ_C 89.0 (C-3) show that *β*-glucose sugar is connected to C-3 in the aglycon part. The good compatibility of its NMR data with those in the literature suggests that compound **1** is 12*β*,20(*R*),25-trihydroxydammara-3-*O*-*β*-D-glucopyranoside.

Compound **2** (15.1 mg): white amorphous powder, highly soluble in pyridine. The ^{13}C-NMR spectrum showed forty-two signals. The NMR data of **2** were similar to those of **1**, except for the additional presence of a *β*-glucose sugar molecule signal with an anomeric proton signal [δ_H 5.39

(1H, d, J = 7.7 Hz, H-1″)] and a carbon signal d_C 106.2 (C-1″). Consequently, compound **2** had an additional *β*-glucose sugar molecule in its structure compared with compound **1**. The good compatibility of its NMR data with those in the literature suggests that **2** was 12*β*,20(*R*),25-trihydroxydammara-3-*O*-*β*-D-glucopyranosyl-(1→2)-*β*-D-glucopyranoside.

Compound **3** (9.2 mg): white amorphous powder, highly soluble in pyridine. The ^{1}H NMR spectrum showed signals of seven methyl groups [δ_H 0.82 (3H, s, CH_3-19), 0.99 (6H, s, CH_3-18, CH_3-30), 1.02 (3H, s, CH_3-29), 1.34 (3H, s, CH_3-28), 1.47 (3H, s, CH_3-21), 1.92 (3H, s, CH_3-27)], two olefin proton signals [δ_H 4.95 (1H, brs, H-26a) and 5.28 (1H, brs, H-26b)], an anomeric proton [δ_H 4.97 (1H, d, J = 7.8 Hz, H-1′)] of *β*-glucose sugar. The ^{13}C-NMR spectrum showed thirty-six signals with two olefin carbon signals [δ_C 150.0 (C-25); 109.9 (C-26)] an anomeric carbon [δ_C 107.0 (C-1′)], five oxygenated carbons of *β*-glucose sugar [75.9 (C-2′), 78.8(C-3′), 71.1 (C-4′), 78.4 (C-5′), 63.2 (C-6′)], four oxygenated carbons of the aglycon part [(δ_C 88.9 (C-3), 72.0 (C-12), 73.2 (C-20), 76.1 (C-24)] and twenty-four signals in the high-field zone (10−55 ppm). The specific signals in the ^{1}H-NMR and ^{13}C-NMR spectra show that compound **3** belongs to the protopanaxadiol dammarane group and has a *β*-glucose moiety in its structure. HMBC cross peak of the anomeric proton at δ_H 4.97 (1H, d, J = 7.8 Hz, H-1') with carbon signal at δ_C 88.9 (C-3) show that *β*-glucose sugar is connected to C-3 in the aglycon part. The good compatibility of its NMR data with those in the literature suggests that **3** was notoginsenosides SFt1.

Compound **4** (9.0 mg): white amorphous powder, highly soluble in methanol and pyridine. The ^{1}H NMR spectrum showed signals of eight methyl groups [δ_H 0.91 (3H, s, CH_3-29), 0.98 (3H, s, CH_3-30), 0.99 (3H, s, CH_3-19), 1.07 (3H, s, CH_3-18), 1.11 (3H, s, CH_3-28), 1.21 (3H, s, CH_3-21), 1.68 (3H, s, CH_3-27), 1.75 (3H, s, CH_3-26)], an anomeric proton [δ_H 4.38 (1H, d, J = 7.8 Hz, H-1′)] of *β*-glucose sugar and an olefin proton signal [δ_H 5.20 (1H, m, H-24)]. The ^{13}C-NMR spectrum showed thirty-six signals with two olefin carbons [δ_C 126.2 (C-24), 132.0 (C-25)], an anomeric carbon [δ_C 106.9 (C-1′)], five oxygenated carbons of *β*-glucose sugar [(δ_C 75.7 (C-2′), 78.3 (C-3′), 71.7 (C-4′), 77.7 (C-5′), 62.9 (C-6′)], three oxygenated carbons of the aglycon part [(δ_C 90.6 (C-3), 72.2 (C-12), 74.4 (C-20)] and twenty-five signals in the high-field zone (10−55 ppm). The specific signals in the ^{1}H-NMR and ^{13}C-NMR spectra show that compound **4** belongs to the protopanaxadiol dammarane group and has a β-glucose moiety in its structure. HMBC cross peak of the anomeric proton at δ_H 4.38 (1H, d, J = 7.8 Hz, H-1′) with carbon signal at δ_C 90.6 (C-3) show that *β*-glucose sugar is connected to C-3 in the aglycon part. Additionally, its ESI-MS showed a molecular ion peak at *m/z* 644.79 $[M–H+Na]^+$ (calcd. for $[C_{36}H_{61}O_8+Na]^+$, 644.43). The good compatibility of its NMR data with those in the literature suggests that **4** was ginsenosied Rh2.

Compound **5** (18.8 mg): white amorphous powder, highly soluble in methanol and pyridine. The ^{13}C-NMR spectrum showed forty-two signals. The NMR data of **5** were similar to those of **4**, except for the additional presence of a *β*-glucose sugar molecule signal with an anomeric proton signal [δ_H 4.65 (1H, d, J = 7.8 Hz, H-1″)] and a carbon signal d_C 98.3 (C-1″) respectively. Consequently, compound **5** had an additional *β*-glucose sugar molecule in its structure compared with compound **4**. Additionally, its ESI-MS showed a molecular ion peak at *m/z* 807.11 $[M+Na]^+$ (calcd. for $[C_{42}H_{72}O_{13}+Na]^+$, 807.48). The good compatibility of its NMR data with those in the literature suggests that **5** was ginsenoside Rg3.

Compound **6** (5.9 mg): white amorphous powder, highly soluble in methanol and pyridine. The ^{13}C-NMR spectrum showed thirty-six signals. The NMR data of compound **6** were similar to those of compound **5**, except for the signals of a methyl ketone group (d_C 213.7 and d_C 30.8) in compound **6**, which differed from the signals of the side-chain (C-20, 21, 22, 23, 24, 25, 26, and 27) in compound **5**. The specific signals in the ^{1}H-NMR and ^{13}C-NMR spectra show that compound **6** belongs to the hexanordammarane group and has two *β*-glucose moiety in its structure. The good compatibility of its NMR data with those in the literature suggests that **6** was notoginsenoside L11.

Research on the biological activities of common saponins has been extensively documented. For instance, ginsenoside Rh2 has been demonstrated to inhibit the proliferation and metastasis of ovarian cancer cells *in vitro* studies.[25–27] Furthermore, it has been observed to enhance insulin secretion while reducing the activity of the *β*-endorphin hormone, which contributes to lower blood sugar levels in experimental mice.[28–30] Ginsenoside Rg3 has shown superior anti-cancer properties compared to many other ginsenosides and has also proven beneficial in diabetes management and blood pressure regulation.[31,32]

To expand the research on the biological activity of saponin compounds derived from Ngoc Linh ginseng, the *α*-glucosidase inhibitory activity was assessed for six compounds (**1**–**6**) as outlined in Table 1. This investigation is the first to evaluate the *α*-glucosidase inhibition of these specific saponin compounds. The results indicated that compounds **1**, **4**, and **6** exhibited significant activity, with

Table 1. The results of α-glucosidase inhibition activities

Compounds	Inhibition percent (%)					IC_{50} (μM)
	250 μM	100 μM	50 μM	25 μM	10 μM	
1	62.1 ± 2.1	42.5 ± 2.0	28.1 ± 4.5	12.06 ± 0.39	6.0 ± 1.4	133.5
2	54.3 ± 4.6	30.8 ± 2.4	11.7 ± 3.0	7.84 ± 0.48	-	217.7
3	19.2 ± 1.4	11.6 ± 5.6	6.8 ± 3.8	-	-	> 250
4	64.9 ± 1.4	58.5 ± 2.6	36.4 ± 9.8	3.1 ± 4.1	-	105.5
5	-	-	-	-	-	> 250
-	25 μM	10 μM	5 μM	2.5 μM	1 μM	-
6	84.7 ± 3.8	35.9 ± 2.3	11.8 ± 4.1	6.3 ± 2.4	4.68 ± 0.53	14.9
Acarbose	250 μM	100 μM	50 μM	25 μM	10 μM	138.2
	59.8 ± 1.2	21.2 ± 2.2	9.8 ± 1.1	3.2 ± 1.7	-	

IC_{50} values of 133.5, 105.5, and 14.9 μM, respectively.

There is an interesting point related to the structure-activity relationship between compounds **5** and **6** as follows: the only difference is the side-chain at C-17, which is 2-hydroxy-6-methylhept-5-en-2-yl in compound **5** compared to a methyl ketone group in compound **6**. However, the results showed that compound **6** (IC_{50} = 14.9 μM) is more active than compound **5** (IC_{50} > 250 μM).

In conclusion, six saponin compounds, including 12β, 20(*R*),25-trihydroxydammara-3-*O*-β-D-glucopyranoside (**1**), 12β,20(*R*),25-trihydroxydammara-3-*O*-β-D-glucopyranosyl-(1→2)-β-D-glucopyranoside (**2**), notoginsenoside SFt1 (**3**), ginsenoside Rh2 (**4**) and ginsenoside Rg3 (**5**) and notoginsenoside L1 (**6**), were isolated for the first time from the leaves of Vietnamese ginseng. The α-glucosidase inhibition assay results showed that compounds **1**, **4**, and **6** exhibited good activities, stronger than the positive control, acarbose.

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Conflicts of Interest

The authors declare that there is no conflict of interest.

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