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New phenylalkanoids from the rhizome of *Cnidium officinalis* Makino

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Abstract

Cnidium officinalis rhizomes were immersed in 80% MeOH. The extract was fractionated to water, *n*-butanol, and ethyl acetate fractions (Fr). Open column chromatography was repeatedly carried out on n-butanol and ethyl acetate Fr using silica gel, octadecyl silica gel, and Sephadex LH-20 as the stationary phase affording five phenyl alkanoids **1**–**5** including two new ones. The molecular structures including stereochemistry were decided based on spectroscopic interpretation of nuclear magnetic resonance, mass spectrometry, and infrared spectroscopy as well as chemical reaction. Three known compounds, coniferyl alcohol methyl ether (**1**), vanillin (**2**), and coniferyl aldehyde (**3**), were reported in the beginning for this plant by authors. Two new phenyl alkanoids were named, 7-methoxyeugenol and cnidiumoside.

Keywords: *Cnidium officinalis*, Cnidiumoside, 7-Methoxyeugenol, Phenyl alkanoid

Introduction

Cnidium officinalis Makino (Umbelliferae) is a perennially grown herb either semi-shaded or not shaded in moist soil. It originates from China but is now extensively cultivated in Korea, Japan, and China [1]. The ground parts have been used as a medicinal, conspicuous aroma, and as condiment materials in beverages, baking, cosmetics, and the pharmaceutical industry [1]. The dried rhizomes (Cnidii Rhizoma) have been especially utilized in East-Asia countries for the treatment of female menstrual disorders and headaches through a decrease in inflammation and an improvement in blood circulation [2, 3]. Many studies have also reported the rhizomes as having anti-cancer [4], analgesic [5], antibacterial [6], anticonvulsive [7], anti-inflammatory [4, 5], febrifuge, hypotensive [8], sedative [9], and vasodilator [10] effects. The major constituents of the rhizomes were revealed to be phthalides, alkaloids, ceramides, polyphenols, and flavonoids [1]. Phthalides in particular are the most important constituents copiously contained in the essential oil [6]. Many reported biological activities of *C. officinalis* rhizomes are due to the presence of phthalides [6]. Phenols are also major constituents of rhizomes and are reported to have various pharmacological activities [11]. However, phenyl alkanoids of this plant are rarely studied. The authors isolated five phenyl alkanoids from *C. officinalis* rhizomes in this study. Among them, two compounds were revealed to be new and three others have never been reported for *C. officinalis*. This paper describes the isolation procedure for phenyl alkanoids and the structure determination including stereostructures.

Materials and methods

Plant materials

Cnidium officinalis rhizomes were provided and identified by Dr. J. T. Jeong, Department of Herbal Crop Research, RDA, Korea. A standard sample (NPCL-20200023) was put up at NPCL Laboratory, KyungHee University, Yongin, Korea.

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General experimental procedures

The instruments and materials used for the isolation and identification of the phenyl alkanoids were the same as those in literatures [12]. The silica gel and the octadecyl silica gel (ODS) resins used for column chromatography (CC) were Kiesel gel 60 (Merck, Darmstadt, Germany) and the Lichroprep RP-18 (40–60 mμ, Merck) respectively. Sephadex LH-20 was purchased from Amersham Biosciences (Uppsala, Sweden). Thin layer chromatography (TLC) was carried out using Kiesel gel 60 F_{254} and RP-18 F_{254S} (Merck) TLC plates, and the spots were detected using a UV lamp Spectroline Model ENF-240 C/F (Spectronics Corporation, Westbury, NY, USA) and a 10% H_2SO_4 solution. Deuterium solvents were purchased from Merck Co. Ltd and Sigma Aldrich Co. Ltd (St. Louis, MO, USA). Nuclear magnetic resonance (NMR) spectra were recorded on a 600 MHz FT-NMR spectrometer (Bruker AVANCE 600, Billerica, MA, USA). Infrared (IR) spectra were obtained using a Perkin Elmer Spectrum One FT-IR spectrometer (Buckinghamshire, England). The specific rotation value was measured with JASCO P-1010 digital polarimeter (Tokyo, Japan). ESIMS spectra were recorded on a AB SCIEX Q-TOF 5600 (Framingham, MA, USA). Solvents were supplied by Burdick & Jackson (Muskegon, MI, USA).

Isolation of phenyl alkanoids from *Cnidium officinalis* rhizomes

C. officinalis rhizomes were dried at room temperature and 10 kg of dried materials were powdered and soaked overnight in ethanol (70%, 54 L × 2) at room temperature. The obtained solution was evaporated using rotary vacuum evaporator at 40℃ affording a brownish extract (2.1 kg). The residue was divided using systemic solvent fractionation using polarity as ethyl acetate (COE, 280 g), *n*-butanol (COB, 125 g), and water (COW, 1.695 kg) Fr. The column chromatography (CC) for COE (270 g) and COB (120 g) was performed as seen in Figs. 1, 2. Finally, five phenyl alkanoids (**1**, COE-11–5; **2**, COE-13–2-3; **3**, COE-13–2-5; **4**, COE-13–11-12–2; **5**, COB-13–9-13–2) were isolated.

Coniferyl alcohol methyl ether (**1**): *Rf* value on silica gel TLC, 0.72, *n*-hexane–ethyl acetate (1:1); *Rf* value on octadecyl silica gel TLC, 0.85, acetone–H_2O (3:1); IR (LiF plates) ν_{max} 3393, 2933, 1676, 1599, 1512, 1463 cm^{-1}; ^{13}C and ^{1}H NMR (CMR and PMR): Tables 1 and 2. EI-MS: *m*/z 180 $[M]^+$.

Vanillin (**2**): *Rf* value on silica gel TLC, 0.29, *n*-hexane–ethyl acetate (2:1); *Rf* value on octadecyl silica gel TLC, *Rf* 0.70, acetone–H_2O (2:1); IR (LiF plates) ν_{max} 3234, 2923, 1675, 1585, 1509 cm^{-1}; CMR and PMR: Tables 1 and 2. EI-MS: *m*/z 152 $[M]^+$.

Coniferyl aldehyde (**3**): *Rf* value on silica gel TLC, 0.20, *n*-hexane– ethyl acetate (2:1); *Rf* value on octadecyl silica gel TLC, *Rf* 0.72, acetone–H_2O (2:1); IR (LiF plates) ν_{max}

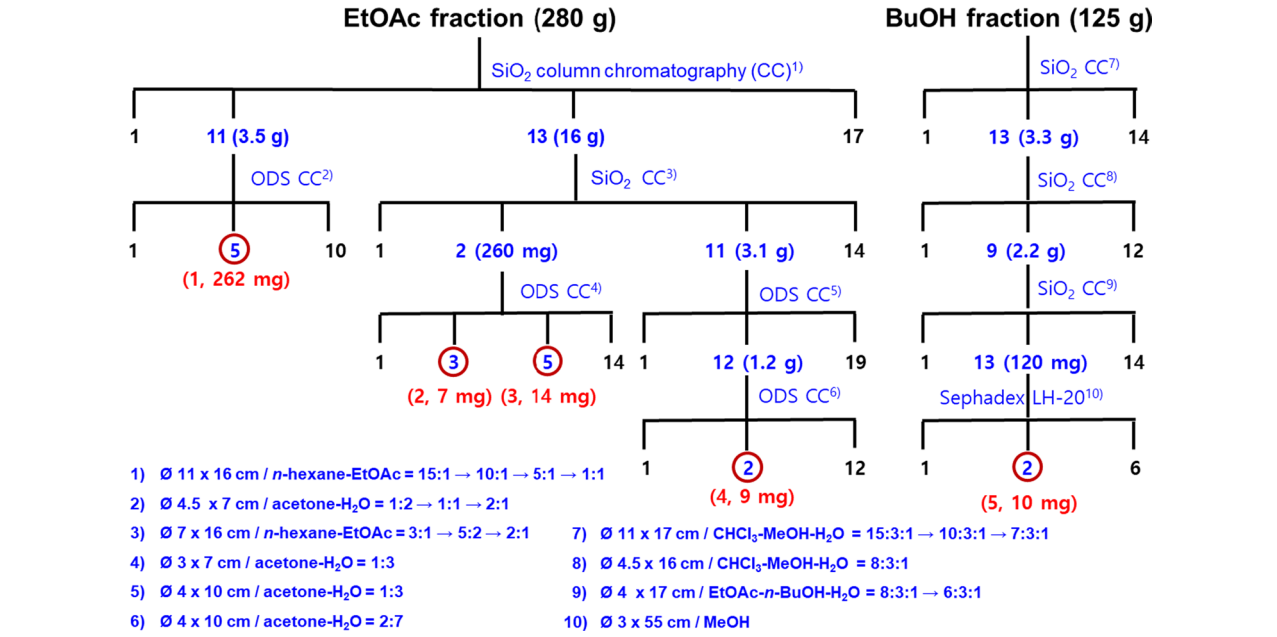

Fig. 1 Isolation of phenyl alkanoids from the rhizomes of *Cnidium officinalis*

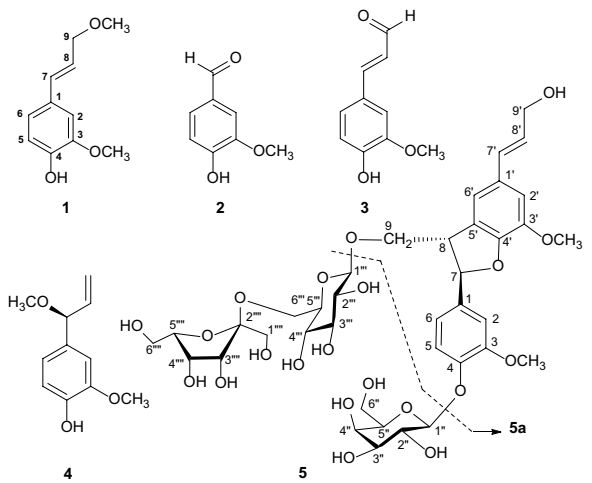

Fig. 2 Chemical structure of phenyl alkanoids from the rhizome of *Cnidium officinalis* Makino. **1**, coniferyl alcohol methyl ether; **2**, vanillin; **3**, coniferyl aldehyde; **4**, 7*S*-7-methoxyeugenol; **5**, cnidiumoside

3183, 2919, 1748, 1660, 1584, 1512 cm^{-1}; CMR and PMR: Tables 1 and 2. EI-MS: *m*/z 178 $[M]^+$

7-Methoxyeugenol (**4**): *Rf* value on silica gel TLC, 0.76, *n*-hexane– ethyl acetate (1:1); *Rf* value on octadecyl silica gel TLC, 0.39, acetone–H_2O (2:1); $[\alpha]_D + 23.2$ (*c* 0.12, CH_3OH); IR (LiF plates) ν_{max} 3153, 2916, 1673,1594, 1510, 1450 cm^{-1}; CMR and PMR: Tables 1 and 2. EI-MS: *m*/z 194.0940 $[M]^+$ (Calcd for $C_{11}H_{14}O_3$ 194.0937).

Cnidiumoside (**5**): *Rf* value on silica gel TLC, 0.54, chloroforem–methanol–H_2O (6:4:1); *Rf* value on octadecyl silica gel TLC, 0.19, methanol–H_2O (1:2); $[\alpha]_D + 15.7$ (*c* 0.10, CH_3OH); IR (LiF plates) ν_{max} 3425, 2996, 1675, 1465 cm^{-1}; CMR and PMR: Tables 1 and 2. High resolution positive ESI–MS: *m*/z 845.3072 $[M+H]^+$ (Calcd for $C_{38}H_{53}O_{21}$ 845.3074).

Acid hydrolysis of cnidiumoside (5)

The solution of 10 mg of **5** in 5 mL of 1N HCl was refluxed for 2 hrs. 15 mL of H_2O was added and treated with ethyl acetate (20 mL × 2). The ethyl acetate phase was concentrated in vacuo and purified via open silica gel CC (2 × 8 cm) using *n*-hexane-ethyl acetate (2:1) as the eluting solution to give a dehydrodiconiferyl alcohol (**5a**, 4 mg).

Dehydrodiconiferyl alcohol (**5a**): $[\alpha]_D$ -49 (*c* 0.18, $CHCl_3$); PMR (600 MHz, $CDCl_3$, δ_H, coupling pattern, *J* in Hz) 6.84 (1H, d, 1.9, H-2), 6.82 (1H, s, H-2′ or H-6′), 6.79 (1H, s, H-2′ or H-6′), 6.50 (1H, dd, 1.9, 8.3, H-6), 6.46 (1H, d, 8.3, H-5), 6.18 (1H, br. d, 16.0, H-7′), 6.14 (1H, dt, 16.0, 5.2, H-8′), 5.50 (1H, d, 6.8, H-7), 4.20 (2H, dd, 5.2, 1.3, H-9′), 3.89 (1H, dd, 11.9, 5.5, H-9a), 3.88 (3H, s, 3-OMe or 3′-OMe), 3.81 (1H, dd, 11.9, 6.3, H-9b), 3.78 (3H, s, 3-OMe or 3′-OMe), 3.56 (1H, ddd, 6.8, 6.3, 6.5, H-8).

Results and discussion

Five phenyl alkanoids **1**–**5** were isolated from the *C. officinalis* rhizome through repeated open column chromatography using octadecyl silica gel, silica gel, and Sephadex LH-20 as the stationary phase. **1**–**3** were identified as coniferyl alcohol methyl ether (**1**) [13], vaniline (**2**), and coniferyl aldehyde (**3**) [14], respectively, from the spectroscopic data and confirmed by previously reported data.

Compound **4** showed a molecular ion peak at *m*/*z* 194.0940 $[M]^+$ in the high resolution EI-MS, establishing the molecular formula as $C_{11}H_{14}O_3$ (Calcd. for $C_{11}H_{14}O_3$ 194.0937). The IR data exhibited the absorbing bands due to hydroxyl (3153 cm^{-1}) and olefin (1673, 1594 cm^{-1}) groups. CMR spectrum (150 MHz, $CDCl_3$) showed 11 signals including two methoxy signals ($\boldsymbol{\delta_C}$ 56.06, OMe-3; 56.40, OMe-7) suggesting **4** to be a phenylpropanoid. Two oxygenated olefin quaternaries ($\boldsymbol{\delta_C}$ 145.36, C-4; 146.84, C-3), one olefin quaternary (δ_C 132.99, C-1), four olefin methines (δ_C 109.14, C-2; 114.24, C-5; 120.32, C-6; 139.00, C-8), one exomethylene (δ_C 116.21, C-9), and one oxygenated methine (δ_C 84.64, C-7) were detected. PMR spectrum (600 MHz, $CDCl_3$) included the olefin signals due to a 1,2,4-trisubstituted benzene moiety [δ_H 6.81, dd, $J = 1.8$, 7.8 Hz, H-6 (δ_H, coupling pattern, *J* in Hz), H-5; 6.86, d, 1.8, H-2; 6.88, d, 7.8), the signals derived from a vinyl moiety (5.20, br. d, 10.2, H-9a; 5.26, br. d, 17.4, H-9b; 5.93, ddd, 6.6, 10.2, 17.4, H-8), an oxygenated methine (4.55, d, 6.6, H-7), and two methoxies (3.31, s, OMe-7; 3.90, s, OMe-3) signals. The NMR data described above were almost identical to eugenol [15] excluding an oxygenated methine and a methoxy moieties instead of a methylene moiety, suggesting that an additional methoxy moiety was linked to C-7. The HMBC spectrum affirmed it; a methoxy proton (δ_H 3.31, OMe-7) correlated with an oxygenated methine carbon (δ_C 84.64, C-7), which also correlated with three olefin methine protons (δ_H 5.93, H-8; 6.81, H-6; 6.86, H-2) and an exomethylene proton (δ_H 5.20, 5.26, H-9). As a result, the planar structure of compound **4** was decided as a 2-methoxy-4-(1-methoxy-2-propen-1-yl) phenol, 7-methoxyeugenol. The stereostructure of chiral center, C-7, could be determined as *S* by comparison of a specific rotation value, $[\alpha]_D + 23.2$, with a previously reported value for 7-hydroxyeugenol [16, 17]. Compound **4** was identified to be 7*S*-7-methoxyeugenol.

Compound **5** exhibited a molecular ion peak at *m*/*z* 845.3072 $[M+H]^+$ in the high resolution ESI–MS, established the molecular formula as $C_{38}H_{52}O_{21}$

Table 1 ^{13}C-NMR data of phenylalkanoids from the rhizome of *Cnidium officinalis* Makino (125 MHz, δ_C)

No of C	Phenylalkanoids*					
	1 ($CDCl_3$)	**2 ($CDCl_3$)**	**3 ($CDCl_3$)**	**4 ($CDCl_3$)**	**5 (CD_3OD)**	
1/1′	129.48	130.20	126.95	132.99	138.22	132.91
2/2′	108.49	109.07	109.76	109.14	111.50	112.37
3/3′	146.81	147.39	147.21	146.84	151.04	145.71
4/4′	145.77	151.91	149.19	145.36	147.74	149.29
5/5′	114.61	114.62	115.19	114.24	118.13	129.89
6/6′	120.56	127.70	124.28	120.32	119.62	116.92
7/7′	132.87	191.03	153.20	84.64	89.01	132.05
8/8′	123.73	-	126.73	139.00	53.39	127.86
9/9′	73.41	-	193.76	116.21	72.57	63.99
3-/3′-OMe	56.05	56.38	56.26	56.06	56.92	56.92
7-/9-OMe	58.07			56.40		
$^{\#}1''/^{\#\#}1'''/^{\#\#\#}1''''$				102.89	104.71	64.69
2″/2‴/2⁗				71.99	75.05	99.34
3″/3‴/3⁗				75.33	§78.35	71.42
4″/4‴/4⁗				69.54	71.49	71.79
5″/5‴/5⁗				77.99	§78.23	83.46
6″/6‴/6⁗				62.95	66.06	62.65
$^{\#}1''/^{\#\#}1'''/^{\#\#\#}1''''$				102.89	104.71	64.69
2″/2‴/2⁗				71.99	75.05	99.34
3″/3‴/3⁗				75.33	§78.35	71.42
4″/4‴/4⁗				69.54	71.49	71.79
5″/5‴/5⁗				77.99	§78.23	83.46
6″/6‴/6⁗				62.95	66.06	62.65

* **1**, coniferyl alcohol methyl ether; **2**, vanilline; **3**, coniferyl aldehyde; **4**, 7*S*-7-methoxyeugenol; **5**, ligusticosiede F

$^{\#}$ Gal, *β*-D-galactopyranosyl; $^{\#\#}$Glc, *β*-D-glucopyranosyl. $^{\#\#\#}$All, *β*-D-allulofuranosyl. §Exchangeable

(Calcd. for $C_{38}H_{53}O_{21}$ 845.3072). The IR data showed the absorption bands due to hydroxyl (3153 cm^{-1}) and phenyl (1673, 1594 cm^{-1}) moieties. Though CMR spectrum (150 MHz, CD_3OD) showed about 50 carbon signals, some of them were revealed from those of impurities included in compound 5. Among them, 38 carbon signals were defined as those of the compound. The 20 signals including two methoxy signals as those of the aglycone moiety and 18 carbon signals due to three hexoses were detected, suggesting that **5** was a lignan triglyceride. CMR spectrum showed two hemiacetals (δ_C 102.89, C-1″; 104.71, C-1‴) and one hemiketal (δ_C 99.34, C-2⁗) carbon signals as well as PMR spectrum showed only two hemiacetal proton signals (4.37, d, 7.8, H-1‴; 4.89, d, 7.8, H-1″), indicating that three sugars in compound **5** were composed of two aldohexoses and one ketohexose. CMR chemical shifts of three sugars confirmed the presence of one terminal *β*- D -galactopyranosyl (δ_C 62.95, C-6″; 69.54, C-4″; 71.99, C-2″; 75.33, C-3″; 77.99, C-5″; 102.89, C-1″) and one terminal *β*-D-allulofuranosyl (δ_C 62.65, C-6⁗; 64.69, C-1⁗; 71.42, C-3⁗; 71.79, C-4⁗; 83.46, C-5⁗; 99.34, C-2⁗) moieties as well as one *β*- D -glucopyranosyl (δ_C 71.49, C-4‴; 75.05, C-2‴; 78.23, C-5‴; 78.35, C-3‴; 104.71, C-1‴) with a downshifted oxygenated methylene signal (δ_C 66.06, C-6‴) due to a glycosidation shift [18] indicating a terminal sugar to be connected to the hydroxyl group at C-6‴ of a glucopyranosyl moiety. The coupling constants of two hemiacetal protons were 7.8 and 7.8 Hz confirming the anomer hydroxyl groups of both aldohexose moieties to have a *β*-configuration. The carbon signals of the aglycone moiety included four oxygenated olefin quaternaries ($\boldsymbol{\delta_C}$ 145.71, C-3′; 147.74, C-4; 149.29, C-4′; 151.04, C-3), three olefin quaternaries ($\boldsymbol{\delta_C}$ 129.89, C-5′; 132.91, C-1′; 138.22, C-1), seven olefin methines ($\boldsymbol{\delta_C}$ 111.50, C-2; 112.37, C-2′; 116.92, C-6′; 118.13, C-5; 119.62, C-6; 127.86, C-8′; 132.05, C-7′), one oxygenated methine ($\boldsymbol{\delta_C}$ 89.01, C-7), two oxygenated methylenes ($\boldsymbol{\delta_C}$ 63.99, C-9′; 72.57, C-9), two methoxies ($\boldsymbol{\delta_C}$ 56.92 × 2), and one methine ($\boldsymbol{\delta_C}$ 53.39, C-8) signals. The

Table 2 ^{1}H-NMR data of phenyl alkanoids from the rhizome of *Cnidium officinalis* Makino (600 MHz, δ_H, coupling pattern, *J* in Hz)

No of C	Phenylalkanoids*					
	1 ($CDCl_3$)	**2 ($CDCl_3$)**	**3 ($CDCl_3$)**	**4 ($CDCl_3$)**	**5 (CD_3OD)**	
2/2′	6.91, br.s	7.40, d, 1.8	7.05, d, 1.8	6.86, d, 1.8	7.08, br. s	6.85, br.s
5/5′	6.83, d, 8.4	7.02, d, 8.4	6.94, d, 8.4	6.88, d, 7.8	7.14, d, 8.4	–
6/6′	6.86, br.d, 8.4	7.41, dd, 1.8, 8.4	7.09, dd, 1.8, 8.4	6.81, dd, 1.8, 7.8	6.98, br.d, 8.4	7.01, br. s
7/7′	6.50, d, 15.6	9.81, d	7.38, d, 16.2	4.55, d, 6.6	5.70, d, 8.0	6.53, br. d, 15.6
8/8′	6.10, dt, 7.0, 15.6		6.57, dd, 7.8, 16.2	5.93, ddd, 6.6, 10.2, 17.4	3.64, overlapped	6.23, dt, 15.6, 5.0
9/9′	4.05, d, 7.0		9.63, d, 7.8	5.26, br. d, 17.4 5.20, br. d, 10.2	4.24, dd, 4.0, 10.2 3.77, overlapped	4.20, d, 5.0
3-/3′-OMe	3.87, s		3.93, s	3.90, s	3.84, s	3.89, s
7-/9-OMe	3.36, s			3.31, s		
#1″/##1‴					4.89, d, 7.8	4.37, d, 7.8
2″/2‴					3.78, overlapped	3.23, dd, 7.8, 7.8
3″/3‴					3.48, overlapped	§3.39, overlapped
4″/4‴					3.78, overlapped	3.38, overlapped
5″/5‴					3.45, overlapped	§a3.28, overlapped
6″/6‴					3.86, overlapped 3.65, overlapped	3.65, overlapped 3.47, overlapped
###1⁗					3.61, overlapped 3.48, overlapped	
3⁗					3.83, overlapped	
4⁗					3.28, overlapped	
5⁗					3.73, overlapped	
6⁗					3.85, overlapped 3.67, overlapped	

* **1**, coniferyl alcohol methyl ether; **2**, vanilline; **3**, coniferyl aldehyde; **4**, 7*S*-7-methoxyeugenol; **5**, ligusticosiede F. #Gal, *β*-D-galactopyranosyl; ##Glc, *β*-D-glucopyranosyl. ###All, *β*-D-allulofuranosyl. §Exchangeable

oxygenated methylene carbon was shifted down-field compared to the usual one, confirming it to be linked to a sugar. PMR spectrum exhibited proton signals due to one 1,2,4-trisubstituted benzene ring (6.98, br. d, 8.4, H-6; 7.08, br. s, H-2; 7.14, d, 8.4, H-5), one 1,2,3,5-tetrasubstituted benzene ring (6.85, br. s, H-2′; 7.01, br. s, H-6′), a double bond with a *trans* configuration (6.23, dt, 15.6, 5.0, H-8′; 6.53, br. d, 15.6, H-7′), one oxygenated methine (5.70, d, 8.0, H-7), two oxygenated methylenes (4.20, d, 5.0, H-9′; 3.77, overlapped, H-9a; 4.24, dd, 4.0, 10.2, H-9b), two methoxies (3.84, s, OMe-3; 3.89, s, OMe-3′), and one methine (δ_H 3.64, overlapped, H-8) moieties. The aforementioned NMR data suggested the aglycone to be a neolignan with a coniferyl alcohol and a dehydroconiferyl alcohol moieties. In the HMBC spectrum, the oxygenated methine proton signal (δ_H 5.70, H-7) showed cross peaks with one oxygenated olefin quaternary (δ_C 149.29, C-4′), two olefin quaternaries (δ_C 129.89, C-5′; 138.22, C-1), two olefin methines (δ_C 111.50, C-2; 119.62, C-6), one oxygenated methylene (δ_C 72.57, C-9), and one methine (δ_C 53.39, C-8) carbon signals. The methine proton signal (δ_H 3.64, H-8) correlated with the carbon signals due to one oxygenated olefin quaternary (C-4′), two olefin quaternaries (C-1 and C-5′), one olefin methine (δ_C 116.92, C-6′), and one oxygenated methylene (C-9) moieties. Therefore, the two phenylpropanoid moieties of neolignan were linked at C-7 and C-4′ through an ether bond and at C-8 and C-5′. The anomer proton signals of one *β*-D-galactopyranosyl and one *β*-D-glucopyranosyl moieteies (δ_H 4.37, H-1‴ and 4.89, H-1″) showed correlations with the oxygenated olefin quaternary (δ_C 147.74, C-4) and the oxygenated methylene (C-9) carbon signals, respectively, as well as the anomer carbon signal of a *β*-D-glucopyranosyl moiety (δ_C 104.71, C-1‴) correlated with the proton signals of an oxygenated methylene moiety (δ_H 3.77 and 4.24, H-9). Long-range coupling between the anomer carbon signal of the *β*-D-allulopyranosyl moiety (δ_C 99.34, C-2⁗) and the oxygenated methylene proton signals (δ_H 3.47 and 3.65, H-6‴) of the *β*-D-glucopyranosyl moiety in the HMBC spectrum were detected. The HMBC correlations described above concluded the linkage position of three sugars as seen in Fig. 1. The relative stereostructure

between H-7 and H-8 was determined to be a *trans* configuration because the cross peak was not observed between H-7 (δ_H 5.70) and H-8 (δ_H 3.64) but was observed between H-7 and H-9 (δ_H 3.77 and 4.24) in the NOESY spectrum. The glycoside, compound **5**, was treated with 1 N HCl and refluxed at 90℃ for two hours to finally yield the aglycone, dehydrodiconiferyl alcohol (**5a**). The dehydroconiferyl alcohol moiety with two chiral carbons, C-7 and C-8, has four stereoisomers, that showed typical specific rotation value [19]. **5a** had an *erythro*-configuration between C-7 and C-8 and the specific rotation value was measured to be -49, confirming the absolute stereostructue of C-7 and C-8 to be *R* and *S*, respectively. Finally, the chemical structure of compound **5** was determined to be (2*R*,3*S*)-4-*O*-*β*-D-galactopyranosyl-9-[(6-*O*-*β*-D-allulofuranosyl-*β*-D-gucopyranosyl)oxy] dehydrodiconiferyl alcohol as seen in Fig. 1. It was revealed to be a new compound, named cnidiumoside.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13765-021-00650-1.

Additional file 1: Fig. S1. ^{1}H and ^{13}C NMR spectra of coniferyl alcohol methyl ether (**1**). **Fig. S2.** ^{1}H and ^{13}C NMR spectra of vanilline (**2**). **Fig. S3.** ^{1}H and ^{13}C NMR spectra of coniferyl aldehyde (**3**). **Fig. S4.** ^{1}H and ^{13}C NMR spectra of 7*S*-7-methoxyeugenol (**4**). **Fig. S5**. ^{1}H-^{1}H COSY and HSQC spectra of 7*S*-7-methoxyeugenol (**4**). **Fig. S6**. HMBC spectrum of 7*S*-7-methoxyeugenol (**4**). **Fig. S7**. ^{1}H and ^{13}C NMR spectra of cnidiumoside (**5**). **Fig. S8**. ^{1}H-^{1}H COSY and HMQC spectra of cnidiumoside (**5**). **Fig. S9**. HMBC spectra of cnidiumoside (**5**). **Fig. S10**. NOESY spectrum of cnidiumoside (**5**).

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Authors' contributions
N-IB planned the study and wrote the paper. H-GK, TNN, and Y-GL isolated phenyl alkanoids. MHL, DYL, Y-HL, and N-IB determined the chemical structures of phenyl alkanoids. All authors read and approved the final manuscript.

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Availability of data and materials
The data and materials used in this study are available under permission from the corresponding author on reasonable request.

Declarations

Competing interests
There are no conflicts to declare.

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