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Flavonoids from the branches and leaves of *Erythrina variegata* L. and their PTP1B and α-glucosidase inhibitory activities

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Abstract. Phytochemical investigation of the methanolic extract of the Vietnamese *Erythrina variegata* branches and leaves resulted in the separation and identification of five flavanones, including 7,4'-dihydroxy-3'-methoxyflavanone (**1**), abyssinone VII (**2**), sigmoidin B (**3**), aromadendrin (**4**), and sigmoidin D (**5**). Their chemical structures were confirmed by the nuclear magnetic resonance (NMR) spectral analysis. These isolated compounds showed inhibitory activities toward two enzymes PTP1B and α-glucosidase, exhibiting varying levels of inhibition. Especially, metabolite **2** strongly inhibited the two enzymes with IC_{50} values of 8.34 ± 0.67 and 12.14 ± 0.39 µM, respectively. In general, hydroxylation at carbons C-5/C-3' and prenylation at C-3′/C-5′ mainly caused active enhancements of these metabolites against both enzyme activities.

Keywords: Erythrina variegata, flavanones, PTP1B inhibitor, α-glucosidase.

Classification numbers: 1.1.1, 1.1.6.

1. INTRODUCTION

Erythrina variegata L. is a flowering plant belongs to the genus *Erythrina* (the family Fabaceae), which is native to tropical and subtropical areas [1]. This species is a woody plant up to 10 m tall with short, conical thorns on its trunk and branches. The compound leaves are

alternate, with three triangular leaflets, whereas the flowers and seeds are crimson and black, respectively. The parts of this species have used in ancient medicine to treat many types of disease. The leaves were used to prepare a drink in Pohnpei, India, and occasionally administered to cure edema conditions of the eyes [2]. The juice from the leaves was mixed with honey to treat worms, and stimulate lactation and menstruation. The barks were combined with other ingredients and utilized as a stomachache remedy. In Southeast Asia and China, the barks and leaves were a component of numerous traditional remedies, one of which was claimed to eliminate harmful parasites and joint discomfort [2].

Accumulating evidence indicated that the medicinal plant *E. variegata* is a good reservoir of alkaloids, phenylpropanoids, benzofurans, terpenoids, and steroids, especially in terms of flavonoids [3]. It is also noted that crude extracts and isolated compounds from this species have possessed a great variety of pharmacological activities, such as anticancer, antioxidant, anti-inflammatory, antibacterial, antidiabetic, enzymatic inhibitory, metal removal, cardiovascular, and relaxant activities, as well as the protections to bone, and central nervous system [2, 3]. For instance, *E. variegata* is used as a natural alternative to hormone replacement therapy to treat and prevent bone loss in postmenopausal women since the 65 % methanolic extract of its stem barks at the doses of 300 and 600 mg/kg could prevent the estrogen deficiency-mediated decrease in trabecular thickness and area, and restore an increase in trabecular separation in mice [4]. Two flavones daidzein and glycitein isolated from the stems and leaves were comparable with the standard compound acarbose in α-glucosidase enzymatic inhibition [3].

This study aims to report the isolation and structural elucidation of flavanone derivatives from *E. variegata* branches and leaves, collected from Ha Noi, Viet Nam. These phytochemicals have been further subjected to PTB1B and α-glucosidase enzymatic inhibitions.

2. PLANT AND EXPERIMENT

2.1. Experimental equipment

NMR spectral data were measured on a spectrometer AVANCE 500 series of Bruker. Silica gel normal phase and reverse phase are from Merck. Thin layer chromatography (TLC) was performed using both silica gel NP and RP F_{254} plates. Agilent 1260 HPLC system was used for isolation and purification popose with a RP_C18 column (10 × 250 mm, 5 µm particle size). CH_3CN and MeOH solvents were purchased from Fisher Scientific Korea Ltd. for HPLC purification.

2.2. Plant materials

The branches and leaves of the studied plant were gathered from Ha Noi, Viet Nam, in June 2021.

2.3. Isolation and purification of compounds

The branches and stems material are dried by at 50 ºC before grinding into powder. The powder is then extracted with ethanol (15 L × 03 times) by using sonication for 120 min. The solution was then filtered before evaporation by a rotary evaporator to yield a total ethanol extract. This extract was then fractionated by *n*-hexane (3.0 L × 3 times), to get the soluble *n*-

hexane fraction, and the crush extract residue. This residue was further diluted with EtOAc (3.0 L × 3 times). The resulting supernatant was then filtered, and the solvent was removed via vacuum distillation to yield the EtOAc extract (58 g). A part of this extract (50 g) was subjected onto a silica gel column (10 × 80 cm) chromatography and diluting with gradient solvent system of hexane and acetone (starting from 20:1 to 1:5, v/v), to afford 15 fractions (F.1 – F.15). The fraction F.12 was further separated by reversed phase column C-18, using methanol-water, 1:5–5:1, v/v, to give a pure compound **1** (16 mg) and 8 subfractions F12.1–F12.8. The subfraction F12.4 was then subjected to an open column (2.5 × 60 cm), using normal phase silica gel (150 µm), and diluted with a system of 85 % CH_2Cl_2 in MeOH as isocratic solvent to yield compounds **4** (11.2 mg) and **5** (4.8 mg). Similarly, the subfraction F12.6 was also chromatographed on an open column (2.5 × 60 cm) using normal phase silica gel (150 µm, particle size), eluting by a solvent systemt of CH_2Cl_2–MeOH (from 8:1 to 4:1, v/v), resulting in the purification of compounds **2** (17.5 mg) and **3** (5.4 mg).

7,4′-Dihydroxy-3′-methoxyflavanone (**1**): White solids; ^{1}H-NMR (300 MHz, acetone-d_6, δ_H ppm): 7.71 (1H, d, J = 8.7 Hz, H-5), 7.19 (1H, d, J = 1.8 Hz, H-2'), 7.00 (1H, dd, J = 1.8, 8.1 Hz, H-6'), 6.56 (1H, dd, J = 2.1, 8.7 Hz, H-6), 6.50 (1H, d, J = 8.1 Hz, H-5'), 6.41 (1H, d, J = 2.1 Hz, H-8), 5.42 (1H, dd, J = 3.0, 13.2 Hz, H-2), 3.07 (1H, dd, J = 13.2, 16.5 Hz, H-3$_{ax}$), 2.65 (1H, dd, J = 3.0, 16.5 Hz, H-3$_{eq}$), 3.87 (3H, s, 3'-OCH_3).

Abyssinone VII (**2**): Yellow solids; ^{1}H-NMR (300 MHz, acetone-d_6, δ_H ppm): 7.70 (1H, br d, J = 6.9 Hz, H-5), 6.90 (1H, s, H-6'), 6.80 (1H, s, H-2'), 6.55 (1H, br d, J = 6.9 Hz, H-6), 6.40 (1H, brs, H-8), 5.36 (1H, dd, J = 3.0, 13.2 Hz, H-2), 5.33 (1H, m, H-2"), 3.34 (2H, br d, J = 6.9 Hz, H-1"), 3.06 (1H, dd, J = 13.2, 16.5 Hz, H-3$_{ax}$), 2.65 (1H, dd, J = 3.0, 16.5 Hz, H-3$_{eq}$), 1.70 (6H, s, 4"/5"-CH_3.

Sigmoidin B (**3**): White amorphous solids; ^{1}H-NMR (300 MHz, acetone-d_6, δ_H ppm): 12.1 (1H, s, 5-OH), 6.86 (1H, s, H-2'), 6.76 (1H, s, H-6'), 5.90 (2H, brs, H-6/H-8), 5.31 (1H, dd, J = 3.0, 13.2 Hz, H-2), 5.29 (1H, m, H-2"), 3.31 (2H, br d, J = 7.2 Hz, H-1"), 3.07 (1H, dd, J = 13.2, 16.5 Hz, H-3$_{ax}$), 2.71 (1H, dd, J = 3.0, 16.5 Hz, H-3$_{eq}$), 1.71 (6H, s, 4"/5"-CH_3).

Aromadendrin (**4**) - White crystals; ^{1}H-NMR (300 MHz, acetone-d_6) δ_H (ppm): 11.7 (1H, s, H-5), 7.41 (2H, d, J = 8.4 Hz, H-2'/H-6'), 6.88 (2H, d, J = 8.4 Hz, H-3'/H-5'), 5.97 (1H, d, J = 1.8 Hz, H-8), 5.93 (1H, d, J = 1.8 Hz, H-6), 5.06 (1H, d, J = 11.4 Hz, H-2), 4.64 (1H, d, J = 11.4 Hz, H-3).

Sigmoidin D (**5**) - Colorless crystal; ^{1}H-NMR (500 MHz, acetone-d_6) δ_H (ppm): 6.85 (1H, s, H-2'), 6.74 (1H, s, H-6'), 5.97 (1H, s, H-8), 5.95 (1H, s, H-6), 5.37 (1H, dd, J = 3.0, 13.0 Hz, H-2), 3.82 (1H, dd, J = 5.5, 13.0 Hz, H-2"), 3.15 (1H, dd, J = 13.0, 17.0 Hz, H-1"$_{ax}$), 3.01 (1H, dd, J = 13.0, 17.0 Hz, H-3$_{ax}$), 2.73 (1H, dd, J = 5.5, 17.0 Hz, H-1"$_{eq}$), 2.71 (1H, dd, J = 3.0, 17.0 Hz, H-3$_{eq}$), 1.37 (3H, s, 4′′-CH_3), 1.27 (3H, s, 5′′-CH_3).

2.4. The protein tyrosine phosphatase 1B (PTP1B) and α-glucosidase inhibitory assays

The PTB1B inhibitory assay method was described in our previous report [5]. The IC_{50} value was the lowest concentration of PTP1B inhibitor that inhibits 50 % of PTP1B activity. Each experiment was run in triplicate. The positive control in this assay was ursolic acid.

Alpha-glucosidase assay procedure was also described in our previous report [5]. Each experiment was run in triplicate. In this assay, the positive control used as acarbose.

3. EXPERIMENTAL RESULTS

The ^{1}H-NMR spectral data of isolated compounds **1**–**3**, and **5** displayed the signals for aromatic rings, one proton for H-2 as an oxygenated methine, and two proton signals for H_2-3. The ^{13}C-NMR spectral data showed a ketone signal (C=O) for C-4, one oxymethine signal for C-2, one methylene signal for carbon at C-3 (Figure 1). These data revealed a flavanone-type structures for the mentioned isolates. In detail, compound **1** present signals for two aromatic rings, and the signal that resonated at δ_H 5.42 (1H, dd, J = 3.0, 13.2 Hz, H-2) was asigned for an oxymethine H-2, as well as the δ_H 3.07 (1H, dd, J = 13.2, 16.5 Hz, H-3ax) and 2.65 (1H, dd, J = 3.0, 16.5 Hz, H-3eq)/δ_C 44.9 (C-3) can be assigned for a methylene at C-3 position in its ^{1}H- and ^{13}C-NMR spectra.

Six aromatic protons and one additional methoxy group [δ_H 3.87 (3H, s, 3'-OCH_3)/δ_C 56.4 (3'-OCH_3)] were observed. Two ABX-spin system were assigned for these aromatic protons according to their chemical shift and relative coupling constant with δ_H 7.71 (1H, d, J = 8.7 Hz, H-5), 6.56 (1H, dd, J = 2.1, 8.7 Hz, H-6), and 6.41 (1H, d, J = 2.1 Hz, H-8) for ring A, and δ_H 7.19 (1H, d, J = 1.8 Hz, H-2'), 7.00 (1H, dd, J = 1.8, 8.1 Hz, H-6'), and 6.50 (1H, d, J = 8.1 Hz, H-5') for ring B. In the ^{13}C NMR spectrum of compound **1**, the signals of C-2, C-3, and C-4 were resonance at δ_C 80.9, 44.9, and 190.6 ppm, respectively, while the signals assigned for the oxygenated quaternary carbons C-7 and C-9 were observed at 165.4 and 164.6 ppm, respectively. The signals resonated at δ_C 148.5 and 147.8 indicated for two adjacent oxygenated quaternary aromatic carbon C-3′ and C-4′, respectively. Comparing the 1D-NMR spectral data of compound **1** with the references values, compound **1** was characterized to be 7,4′-dihydroxy-3'-methoxyflavanone [6].

Compound **2** possessed one aliphatic oxygenated methine at δ_C 80.7 (C-2), a methylene carbon at δ_C 44.7 (C-3), and one ketone carbon at δ_C 190.5 (C-4), but showed only five aromatic protons with δ_H 7.70 (1H, br d, J = 6.9 Hz, H-5), 6.55 (1H, br d, J = 6.9 Hz, H-6), and 6.40 (1H, br s, H-8) assigned for ring A, and a pair of *meta*-coupling proton at δ_H 6.80 (1H, s, H-2') and 6.90 (1H, s, H-6'). In addition, a prenyl group was observed for compound **2** with typical proton signals at δ_H 5.33 (1H, m, H-2"), 3.34 (2H, br d, J = 6.9 Hz, H-1"), and 1.70 (6H, s, 4"/5"-CH_3) with corresponding carbon signals at δ_C 29.0 (C-1″), 123.5 (C-2″), 132.4 (C-3″), 17.9 (C-4″), and 25.9 (C-5″). In the ^{13}C NMR spectrum of compound **2**, two adjacent oxygenated quaternary carbons were also observed at δ_C 144.1 (C-3′) and 145.1 (C-4′), respectively. Similar to **2**, the ^{1}H and ^{13}C NMR of compound **3** also showed signals assignable for a prenyl group with δ_H 5.29 (1H, m, H-2"), 3.31 (2H, br d, J = 7.2 Hz, H-1"), and 1.71 (6H, s, 4"/5"-CH_3) and δ_C 29.0 (C-1″), 123.5 (C-2″), 132.5 (C-3″), 17.8 (C-4″), and 25.8 (C-5″). But the ^{1}H NMR spectrum showed only two pair of *meta*-coupling protons at δ_H 6.86 (1H, s, H-2'), 6.76 (1H, s, H-6'), and 5.90 (2H, br s, H-6/H-8) of ring A, in addition to a conjugated hydroxyl proton at δ_H 12.1 (1H, s, 5-OH). Similarly, compound **5** also possessed one ketone carbon [δ_C 197.3 (C-4)], an oxymethine [(δ_H 5.37 (1H, dd, J = 3.0, 13.0 Hz, H-2)/δ_C 80.2 (C-2)], and a methylene [δ_H 3.01 (1H, dd, J = 13.0, 17.0 Hz, H-3_{ax}), 2.71 (1H, dd, J = 3.0, 17.0 Hz, H-3_{eq})/δ_C 43.7 (C-3)], and two pair of meta-coupled aromatic protons (H-6/H-8/H-2'/H-6'). However, no signals for a prenyl group was observed in the ^{1}H- and ^{13}C-NMR spectra of compound **5**, instead of that, a 2,2-dimethylpyran unit [δ_H 3.82 (1H, dd, J = 5.5, 13.0 Hz, H-2″)/δ_C 69.9 (C-2″), 3.15 (1H, dd, J = 13.0, 17.0 Hz, H-1″$_{ax}$), 2.73 (1H, dd, J = 5.5, 17.0 Hz, H-1″$_{eq}$)/δ_C 32.1 (C-1″), δ_H 1.37 (3H, s, 4″-CH_3)/δ_C 26.0 (C-4″), and 1.27 (3H, s, 5″-CH_3)/δ_C 20.8 (C-5″)]. Thus, compound **5** is a 5,7-

dihydroxyflavanone bearing a hydroxy group [δ_C 142.0 (C-3′)] and a 2,2-dimethylpyran unit in ring B. After carefully comparing the literature data with NMR data of the isolated compounds (**2**–**3**, and **5**), let to the structure identification of these compounds as abyssinone VII (**2**), sigmoidin B (**3**), and sigmoidin D (**5**) [6–11].

Compound **4** showed six characteristic aromatic proton signals in its ^{1}H-NMR spectrum, of which two *meta*-coupling protons were assigned for A ring at δ_H 5.97 (1H, d, J = 1.8 Hz, H-8) and 5.93 (1H, d, J = 1.8 Hz, H-6), and the remaining signals at δ_H 7.41 (2H, d, J = 8.4 Hz, H-2′/H-6′), 6.88 (2H, d, J = 8.4 Hz, H-3′/H-5′) were characterized for the AA′BB′-spin system of ring B. The ^{13}C-NMR spectrum of **4** revealed the signal of a ketone [δ_C 198.2 (C-4)], oxygenated aliphatic carbons at δ_C 84.4 (C-2) and 73.1 (C-3), and oxygenated quaternary aromatic carbons at δ_C 164.8 (C-5), 168.1 (C-7), 164.3 (C-4′), and 158.9 (C-9), and 2 quaternary carbons at δ_C 129.2 (C-1′) and 101.5 (C-10). These ^{1}H- and ^{13}C-NMR data of **4** and the literature data [12] were compatibility leading to the characterization of **4** to be dihydrokaempferol or aromadendrin.

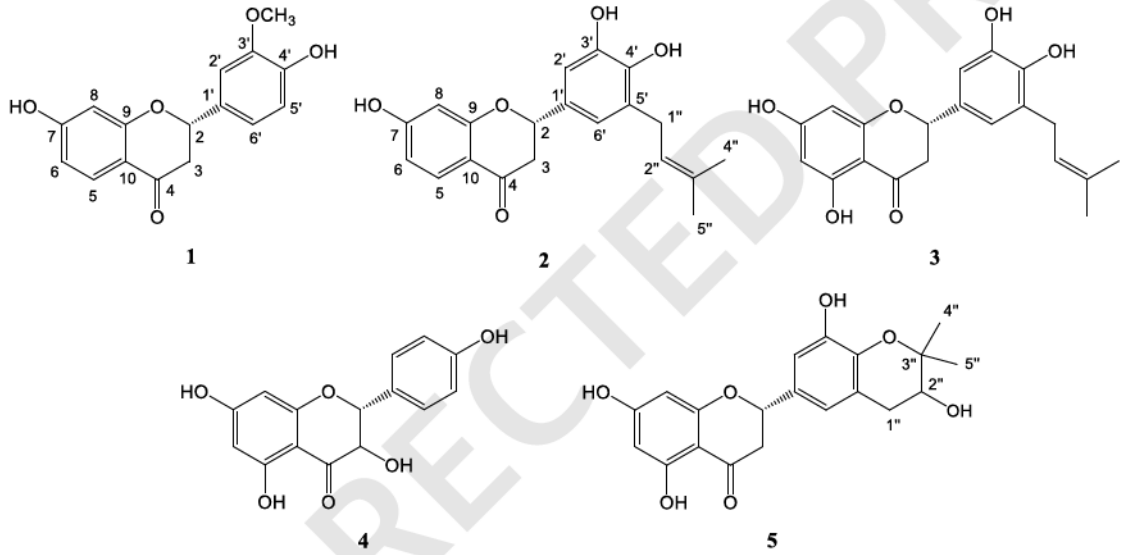

Figure 1. The chemical structures of flavonoids **1**–**5**.

Table 1. Compounds **1**–**5** were measured in acetone-d_6 at 100 MHz for ^{13}C NMR.

Carbon	**Comp. 1**	**Comp. 2**	**Comp. 3**	**Comp. 4**	**Comp. 5**
	δ_C (ppm)	δ_C (ppm)	δ_C (ppm)	δ_C (ppm)	δ_C (ppm)
2	80.9	80.7	80.1	84.4	80.2
3	44.9	44.7	43.5	73.1	43.7
4	190.6	190.5	197.2	198.2	197.3
5	129.6	129.4	165.2	164.8	165.1
6	111.3	111.0	96.6	97.1	96.7
7	165.4	165.1	167.1	168.1	167.3
8	103.7	103.6	95.7	96.1	95.9
9	164.6	164.4	164.3	158.9	164.5
10	115.3	115.2	103.1	101.5	103.2

1'	131.9	131.0	130.5	129.2	131.7
2'	115.7	112.0	112.0	130.4	112.1
3'	148.5	144.1	144.2	115.9	142.0
4'	147.8	145.1	145.1	164.3	146.9
5'	111.2	128.9	128.9	115.9	121.1
6'	120.6	120.6	120.0	130.4	119.4
1"		29.0	29.0		32.1
2"		123.5	123.5		69.9
3"		132.4	132.5		78.7
4"		17.9	17.8		26.0
5"		25.9	25.8		20.8
3'-OCH_3	56.4				

Compounds **1** and **2** have been first isolated from this plant species and tested for their biological activities. Compound **3** was studied and show the inhibition on DPPH and arachidonic acid metabolism. Compound **3** proved to be potent scavengers of the DPPH radical and a selective inhibitor of 5-lipoxygenase. In addition, the compound was also decreased the induced oedema by 83 % in mouse ears by 12-O-tetradecanoylphorbol 13-acetate (TPA) and the phospholipase A2-induced mouse paw oedema [13]. Compound **4** was previously isolated from *G. sinensis* and significantly show insulin-sensitive glucose uptake stimulation in both HepG2 cells and 3T3-L1 adipocytes at a concentration of 30 µM. Moreover, compound **4** also enhanced adipogenesis and increased PPARγ2 as well as aP2 mRNAs expression in differentiated 3T3-L1 adipocytes leading to the glucose uptake stimulation and decreasing insulin resistance [14]. In addition, aromadendrin was found to protect neuronal cells from methamphetamine-induced neurotoxicity by regulating endoplasmic reticulum stress and PI3K/Akt/mTOR signaling pathway [15]. Sigmoidin D (**5**), a prenylated flavanone was first isolated from *Erythrina sigmoidea* in 1986, and then from *Erythrina abyssinica* in 1988. Lately, the compound was found in *Erythrina latissima* and evaluated for its anti-genotoxic ability to inhibit genotoxicity induced by aflatoxin B1 [16].

Compounds **1**–**5** have been subjected to PTP1B and α-glucosidase inhibitory activities. As shown in Table 2, compound **2** acted as a good PTP1B inhibitor showing an IC_{50} inhibitory value of 8.34 ± 0.67 µM, while ursolic acid, as a positive control, showed an IC_{50} 3.31 ± 0.19 µM. The remaining compounds run in a visible order of **4** (IC_{50} 12.21 ± 0.77 µM) > **3** (IC_{50} 19.40 ± 2.30 µM) > **5** (IC_{50} 31.77 ± 0.33 µM) > **1** (IC_{50} 98.10 ± 11.30 µM). Generally, hydroxylation at carbons C-3' and prenylation at carbons C-5' would increase inhibitory capacities when compound **1** compared to compounds **2** and **3**. The activity of compound **2** is better than that of compounds **3**–**5**, suggesting that hydroxylation has more effects than prenylation. Compound **5** displayed less inhibitory activity than compound **3**. It may be due to the cyclization of the prenyl group with the 4'-OH group at C-3". *Erythrina* constituents are likely a potential source of the PTP1B inhibitors. Pterocarpan-type flavonoids from the ethyl acetate extract of *E. abyssinica* stem barks established great effects against the PTP1B enzymes with IC_{50} values ranging from 4.20 to 19.3 µM [13]. Our previous publication also reported that three flavonoids eryvarins H and M, and neobavaisoflavone from *E. variegata* caused IC_{50} values of 9.23 to 20.31 µM in PTP1B inhibitory assay [14].

Table 2. The inhibition of PTP1B and α-glucosidase by flavonoids **1**–**5**.

Compounds	Inhibitory activity (IC_{50}, μM)	
	PTP1B	α-Glucosidase
1	98.10 ± 11.30	> 200
2	8.34 ± 0.67	12.14 ± 0.39
3	19.40 ± 2.30	195.55 ± 0.79
4	12.21 ± 0.77	66.19 ± 1.30
5	31.77 ± 0.33	86.15 ± 0.35
ursolic acid [a]	3.31 ± 0.19	- [c]
acarbose [b]	-	151.4 ± 1.50

[a] Compound used as positive control for PTP1B assay; [b] Compound used as positive control for α-glucosidase assay; [c] not tested.

Isolated flavonoids **1**–**5** also exhibited different capacities in α-glucosidase inhibitory assay. Again, abyssinone VII (**2**) gave the best activity with the IC_{50} value of 12.14 ± 0.39 μM, followed by **4** (IC_{50} 66.19 ± 1.30 μM) > **5** (IC_{50} 86.15 ± 0.35 μM) > acarbose (IC_{50} 151.4 ± 1.50 μM) > **3** (IC_{50} 195.55 ± 0.79 μM) > **1** (IC_{50} > 200 μM, inactive). In the same manner as the PTP1B assay, this result reflected a great role of hydroxylation and prenylation at carbons C-3'/C-5', as well as hydroxylation seems better than prenylation. *E. variegata* constituents are likely potential agents for antidiabetic. Our previous reports also investigated the effects of various *E. variegata* flavonoids in α-glucosidase examinations, such as daidzein, genistein, glycitein, daidzin, eryvarins H and M, and neobavaisoflavone [3, 14].

4. CONCLUSIONS

This is the first time that five flavanone derivatives, consisting of 7,4'-dihydroxy-3'-methoxyflavanone (**1**), abyssinone VII (**2**), sigmoidin B (**3**), aromadendrin (**4**), and sigmoidin D (**5**), were detected in the Vietnamese medicinal plant *E. variegata*. These metabolites showed different inhibitory rates against PTP1B and α-glucosidase enzymes. Substitutions by hydroxyl and prenyl groups to the flavanone nucleus are the main cause of active increases. Extensive studies on mechanisms of action to explore the potential of *Erythrina* flavonoids against these enzymes are necessary.

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Declaration of competing interest. The authors declare that they have no conflicts of interest.

REFERENCES

1. Tanaka H., Hirata M., Etoh H., Sako M., Sato M., Murata J., Murata H., Darnaedi D., Fukai T. – Six new constituents from the roots of *Erythrina variegata*. Chem. Biodivers., **1** (2004) 1101–1108. https://doi.org/10.1002/cbdv.200490082.
2. Lingadurai S., Jain A., Barman N. R., Kumar A. – *Erythrina variegata* Linn: A review on morphology, phytochemistry, and pharmacological aspects. Pharmacogn. Rev., **4** (2010) 147–152. https://doi.org/10.4103/0973-7847.70908.
3. Nguyen P.-H., Xayavong S., Trinh N.-T.-V., Quang D. N., Hoa L. T. P., Do T.-T., Vu T.-H., Bui T.-T., Trinh T.-T.-H. – α-Glucosidase inhibitors from the leaves and stems of *Erythrina variegata* L. collected in Hanoi. J. Sci. Technol. Univ. Danang, **21** (2023) 71–74. https://doi.org/10.31130/ud-jst.2023.040e.
4. Zhang Y., Li X.-L., Lai W.-P., Chen B., Chow H.-K., Wu C.-F., Wang N.-L., Yao X.-S., Wong M.-S. – Anti-osteoporotic effect of *Erythrina variegata* L. in ovariectomized rats. J. Ethnopharmacol., **109** (2007) 165–169. https://doi.org/10.1016/j.jep.2006.07.005.
5. To D.-C., Bui T. Q., Nhung N. T. A., Tran Q.-T., Do T.-T., Tran M.-H., Hien P.-P., Ngu T.-N., Quy P.-T., Nguyen T.-H., et al. – On the inhibitability of natural products isolated from *Tetradium ruticarpum* towards tyrosine phosphatase 1B (PTP1B) and α-glucosidase (3W37): An in vitro and in silico study. Molecules, **26** (2021) 3691. https://doi.org/10.3390/molecules26123691.
6. Calanasan C. A., MacLeod J. K. – A diterpenoid sulphate and flavonoids from *Wedelia asperrima*. Phytochemistry, **47** (1998) 1093–1099. https://doi.org/10.1016/s0031-9422(98)80079-4.
7. Fu B., Li H., Wang X., Lee F. S. C., Cui S. – Isolation and identification of flavonoids in licorice and a study of their inhibitory effects on tyrosinase. J. Agric. Food Chem., **53** (2005) 7408–7414. https://doi.org/10.1021/jf051258h.
8. Nakanishi K., S. Kamat V., Y. Chuo F., Kubo I. – Antimicrobial agents from an East African medicinal plant. Heterocycles, **15** (1981) 1163. https://doi.org/10.3987/s-1981-02-1163.
9. Machumi F., Bojase-Moleta G., Mapitse R., Masesane I., Majinda R. R. T. – Radical scavenging-flavonoids from *Erythrina abyssinica*. Nat. Prod. Commun., **1** (2006) 287–292. https://doi.org/10.1177/1934578x0600100404.
10. Ndom J., Mbafor J. T., Fomum Z. T., Martin M., Bodo B. – ^{1}H and ^{13}C NMR spectral assignment of the prenylflavanones sigmoidins A, B and C, by two-dimensional NMR techniques. Magn. Reson. Chem., **31** (1993) 210–211. https://doi.org/10.1002/mrc.1260310211.
11. Son N. T., Elshamy A. I. – Flavonoids and other non-alkaloidal constituents of genus *Erythrina*: Phytochemical review. Comb. Chem. High Throughput Screen., **24** (2021) 20–58. https://doi.org/10.2174/1386207323666200609141517.
12. Lee E. H., Kim H. J., Song Y. S., Jin C., Lee K.-T., Cho J., Lee Y. S. – Constituents of the stems and fruits of *Opuntia ficus-indica* var. *saboten*. Arch. Pharm. Res., **26** (2003) 1018–1023. https://doi.org/10.1007/bf02994752.
13. Njamen D., Mbafor J. T., Fomum Z. T., Kamanyi A., Mbanya J. C., Recio M. C., Giner R. M., Máñez S., Ríos J. L. – Anti-inflammatory activities of two flavanones, sigmoidin A and sigmoidin B, from *Erythrina sigmoidea*. Planta Med., **70** (2004) 104–107. https://doi.org/10.1055/s-2004-815484.
14. Zhang W. Y., Lee J.-J., Kim I.-S., Kim Y., Myung C.-S. – Stimulation of glucose uptake and improvement of insulin resistance by aromadendrin. Pharmacology, **88** (2011) 266–274. https://doi.org/10.1159/000331862.
15. Lee H.-S., Kim E.-N., Jeong G.-S. – Aromadendrin protects neuronal cells from methamphetamine-induced neurotoxicity by regulating endoplasmic reticulum stress and PI3K/Akt/mTOR signaling pathway. Int. J. Mol. Sci., **22** (2021) 2274. https://doi.org/10.3390/ijms22052274.
16. Zarev Y., Foubert K., Lucia de Almeida V., Anthonissen R., Elgorashi E., Apers S., Ionkova I., Verschaeve L., Pieters L. – Antigenotoxic prenylated flavonoids from stem bark of *Erythrina latissima*. Phytochemistry, **141** (2017) 140–146. https://doi.org/10.1016/j.phytochem.2017.06.003.