Electronic Supplementary Material (ESI) for New Journal of Chemistry.

Supporting Information

Catalytic prenylation of natural polyphenols

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Contents

1. General and Experimental Details

Yields are given for isolated products showing one spot on a TLC plate and no impurities detectable in the NMR spectrum. The identity of the products prepared by different methods was checked by comparison of their NMR spectra.

^{1}H NMR (400 MHz or 500 MHz) and ^{13}C NMR (100 or 125 MHz) spectra were recorded at room temperature; the chemical shifts (δ) were measured in ppm with respect to the solvent ($CDCl_3$, ^{1}H: δ = 7.26 ppm, ^{13}C: δ = 77.16 ppm; DMSO-d_6, ^{1}H: δ = 2.5 ppm, ^{13}C: δ = 39.51 ppm; or tetramethylsilane (TMS), δ = 0 ppm). Coupling constants are given in Hertz. Data are reported as follows: chemical shift (in ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad), coupling constant (*J*, in Hz), and integration. Various 2D-techniques and DEPT experiments were used to establish the structures and to assign the signals. The high resolution mass spectra (HRMS) were recorded in a positive or negative ion mode using electrospray ionization (ESI) from methanol or acetonitrile. All chromatographic manipulations used silica gel (40-63 μm) as the adsorbent.

Melting points were determined on a Kofler block and are uncorrected.

The reaction progress was monitored by GCMS and LCMS analysis and by thin layer chromatography (TLC) on aluminium backed plates with Merck Kiesel 60 F254 silica gel. TLCs were either visualized by UV radiation at a wavelength of 254 nm, or stained by exposure to an ethanolic solution of phosphomolybdic acid.

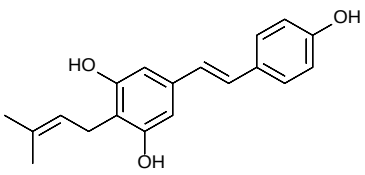
All solvents and reagents for the reactions were of reagent grade and were used as received without further purification.

2. General protocol for prenylation of flavonoids

Flavonoids (1 mmol) was added to the solution of $AlCl_3$ (13.3 mg, 10 mol%) and Silver triflate (25.7 mg, 10 mol%) in acetone (20 ml), the allylic alcohol (2 mmol) in 4 ml acetone was dropwise to the solution under inter atmosphere after 20 mins. The mixture was stirred at room temperature overnight. the reaction was checked by TLC. When the reaction finished, the reaction mixture was extracted with Ethyl acetate and water three times, combined with the organic layer dried by magnesium sulphate, and purified by a short silica chromatography column afford the corresponding compound.

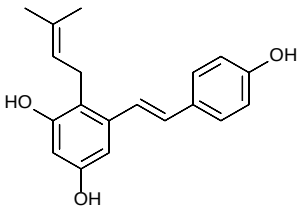
3. Characterization of synthesized compounds

Arachidin-2[S1] (3aa)



Obtained from *trans*-resveratrol (228 mg, 1 mmol) and prenol (172 mg, 2 mmol). White solid (53 mg, 25%), m.p. 131.1-132.7 ºC[lit. 129-130[S1]], R_f = 0.4 (Hexane: Ethyl acetate 3:1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 1.60 (s, 3H), 1.69 (s, 3H), 3.16 (d, *J* = 6.9 Hz, 2H), 5.16 (m, 1H), 6.43 (s, 2H), 6.74 (AA'BB', *J* = 8.6 Hz, 2H), 6.78 (m, 2H), 7.37 (AA'BB', *J* = 8.6 Hz, 2H), 9.10 (s, 2H), 9.54 (s, 1H); **^{13}C NMR** (101 MHz, , DMSO-d_6) δ 17.7, 22.1, 25.5, 104.3(2C), 113.9, 115.5(2C), 123.5, 125.8, 126.8, 127.7(2C), 128.1, 129.4, 135.5, 156.0(2C), 157.1. In agreement with literature[S1].

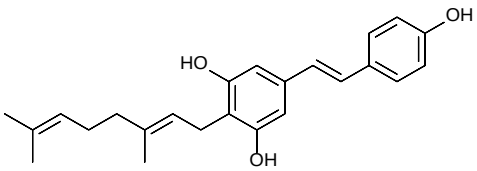
(*E*)-5-(4-hydroxystyryl)-4-(3-methylbut-2-en-1-yl)benzene-1,3-diol (4aa)[S2].



Obtained from *trans*-resveratrol (228 mg, 1 mmol) and prenol (172 mg, 2 mmol). White solid (198 mg, 67 %), m.p. 141.8-142.6 ºC, R_f = 0.52 (Hexane: Ethyl acetate 2:1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 1.60 (s, 3H), 1.73 (s, 3H), 3.29 (d, *J* = 6.8 Hz, 2H), 5.02 (m, 1H), 6.22 (d, *J* = 2.3 Hz, 1H), 6.47 (d, *J* = 2.3 Hz, 1H), 6.76 (AA'BB', *J* = 8.6 Hz, 2H), 6.80 (d, *J* = 16.1 Hz, 1H), 7.06 (d, *J* = 16.1 Hz, 1H), 7.35 (AA'BB', *J* = 8.6 Hz, 2H), 8.96 (s, 1H), 9.12 (s, 1H), 9.54 (s, 1H); **^{13}C NMR** (101 MHz, , DMSO-d_6) δ 17.8, 23.8, 25.5, 101.7, 102.7, 115.5(2C), 116.6, 123.5, 124.5, 126.8, 127.7(2C), 128.5, 128.9, 137.5, 155.7, 155.8, 157.1. In agreement with literature[S2].

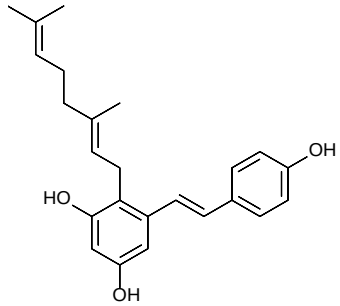
2-((*E*)-3,7-dimethylocta-2,6-dien-1-yl)-5-((*E*)-4-hydroxystyryl)benzene-1,3-diol (3ab)[S3]

Obtained from *trans*-resveratrol (228 mg, 1 mmol) and geraniol (308 mg, 2 mmol). White solid



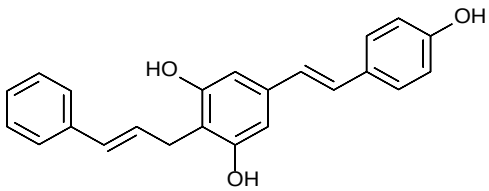
(80 mg, 22 %), m.p. 140.7-143.5 ºC R_f = 0.24 (Hexane: Ethyl acetate 2:1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 1.53 (s, 3H), 1.60 (s, 3H), 1.70 (s, 3H), 1.88 (m, 2H), 1.99 (m, 2H), 3.16 (d, *J* = 6.9 Hz, 2H), 5.05 (m, 1H), 5.17 (m, 1H), 6.43 (s, 2H), 6.74 (, *J* = 8.6 Hz, 2H), 6.78 (m, 2H), 7.38 (AA'BB', *J* = 8.7 Hz, 2H), 9.09 (s, 2H), 9.53 (s, 1H); **^{13}C NMR** (101 MHz, , DMSO-d_6) δ 15.9. 17.5, 22.0, 25.5, 26.3(2C), 104.2(2C), 113.9, 115.5(2C), 123.2, 124.2, 125.8, 126.8, 127.7(2C), 128.1, 130.6, 133.0, 135.5, 156.0(2C), 157.1. In agreement with literature[S3].

Macatrichocarpin F (4ab)[S4]



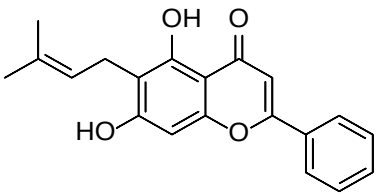
Obtained from *trans*-resveratrol (228 mg, 1 mmol) and geraniol (308 mg, 2 mmol). Coreless oil (254 mg, 70 %), R_f = 0.58 (Hexane: Ethyl acetate 2:1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 1.53 (s, 3H), 1.47 (s, 3H), 1.54 (s, 3H), 1.74 (m, 2H), 1.93 (m, 2H), 3.29 (d, *J* = 6.7 Hz, 2H), 5.01 (m , 2H), 6.22 (d, J = 2.4 Hz, 1H), 6.46 (d, J = 2.4 Hz, 1H), 6.74 (AA'BB', *J* = 8.6 Hz, 2H), 6.79 (d, J = 16.1 Hz, 1H), δ 7.03 (d, J = 16.1 Hz, 1H), 7.33 (AA'BB', *J* = 8.7 Hz, 2H), 8.98 (s, 1H), 9.14 (s, 1H), 9.55 (s, 1H); **^{13}C NMR** (101 MHz, , DMSO-d_6) δ 16.0, 17.5, 23.7, 25.4, 26.2(2C), 101.7, 102.7, 115.5 (2C), 116.6, 123.5, 124.1, 124.5, 127.7(2C), 128.1, 128.8, 130.6, 132.7, 137.7, 155.7, 155.8, 157.2; **HRMS (ESI)** 365.2117 ($C_{24}H_{29}O_3$) $[M+H]^+$ requires 365.2111. In agreement with literature[S4].

5-((*E*)-4-hydroxystyryl)-2-((E)-styryl)benzene-1,3-diol (3ac)

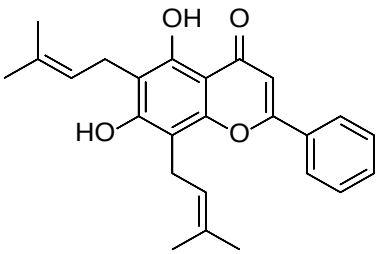


Obtained from *trans*-resveratrol (228 mg, 1 mmol) and cinnamyl alcohol (268 mg, 2 mmol). White solid (206 mg, 60 %), m.p. 123.2-124.5 ºC, R_f = 0.38 (Hexane: Ethyl acetate 2:1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.39 (d, *J* = 4.3 Hz, 2H). 6.32 (m, 2H), 6.49 (s, 2H), 6.75 (AA'BB', *J* = 8.6 Hz, 2H), 6.82 (m, 2H), 7.16 (m, 1H), 7.26 (m, 2H), 7.32 (m, 2H), 7.39 (AA'BB', *J* = 8.6 Hz, 2H), 9.23 (s, 2H), 9.55 (s, 1H); **^{13}C NMR** (126 MHz, , DMSO-d_6) δ 26.4, 104.3(2C), 112.0, 115.5(2C), 125.6(9)(2C), 125.7(2), 126.7, 127.1, 127.8(2C), 128.1, 128.6(2C), 128.9, 129.0, 136.1, 137.5, 156.3(2C), 157.2; **HRMS (ESI)** 345.1486 ($C_{23}H_{21}O_3$) $[M+H]^+$ requires 345.1491.

5,7-Dihydroxy-6-prenylflavon (3ba)[S5]



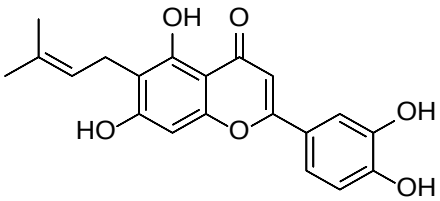
Obtained from chrysin (254 mg, 1 mmol) and prenol (172 mg, 2 mmol). Yellow solid (79 mg, 24 %), m.p. 226.9-227.8 ºC, R_f = 0.6 (Hexane: Ethyl acetate 5:1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 1.63 (s, 3H). 1.73 (s, 3H), 3.23 (d, *J* = 7.2 Hz, 2H), 5.18 (t, *J* = 7.2 Hz, 1H), 6.58 (s, 1H), 6.96 (s, 1H), 7.59 (m, 3H), 8.07 (m, 2H), 10.94 (s, 1H), 13.09 (s, 1H); **^{13}C NMR** (126 MHz, DMSO-d_6) δ 17.7. 21.0, 25.5, 93.4, 103.8, 105.1(2C), 111.2, 122.1, 126.4(2C), 129.2(2C), 130.7(6), 130.8(1), 132.0, 155.3, 158.33, 162.1, 162.9, 181.9. In agreement with literature[S5].



5,7-Dihydroxy-6,8-di-CC-prenylflavon (5ba)[S6]

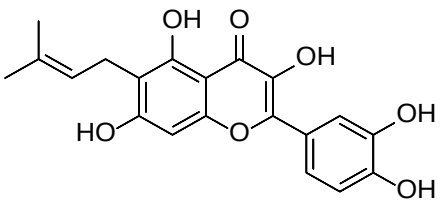
Obtained from chrysin (254 mg, 1 mmol) and prenol (172 mg, 2 mmol). Yellow solid (202 mg, 52 %), m.p. 301.1-302.3 ºC, R_f = 0.3 (Hexane: Ethyl acetate 5:1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 1.63 (s, 6H). 1.73 (s, 3H), 1.76 (s, 3H), 3.23 (d, *J* = 7.2 Hz, 2H), 3.55 (d, *J* = 7.2 Hz, 2H), 5.14 (m, 1H), 6.95 (s, 1H), 7.59 (m, 3H), 8.03 (m, 2H), 9.78 (br.s, 1H), 13.06 (s, 1H); **^{13}C NMR** (126 MHz, , DMSO-d_6) δ 17.7, 18.0, 21.4, 21.8, 25.4, 25.5, 104.1, 104.9, 106.7, 111.8, 122.3, 122.7, 126.3(2C), 129.2(2C), 130.9, 131.1(1), 131.1(4), 132.0, 152.7, 156.3, 159.3, 163.0, 182.3. In agreement with literature[S6].

6-C-prenyl luteolin (3ca)[S7]



Obtained from luteolin (286 mg, 1 mmol) and prenol (172 mg, 2 mmol). Yellow solid (113 mg, 32 %), m.p. 166.5-167.8 ºC, R_f = 0.2 (Hexane: Ethyl acetate 2:1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 1.62 (s, 3H). 1.72 (s, 3H), 3.21 (d, *J* = 6.7 Hz, 2H), 5.16 (t, *J* = 6.7 Hz, 1H), 6.49 (m, 1H), 6.69 (s, 1H), 6.89 (m, 1H), 7.39 (s, 1H), 7.41 (m, 1H), 9.51(br.s, 1H), 10.8 (br.s, 1H), 12.92 (s, 1H) 13.23 (s, 1H); **^{13}C NMR** (101 MHz, , DMSO-d_6) δ 17.4. 25.4, 25.5, 93.4, 98.2. 103.5, 108.4, 119.6, 120.3, 124.0, 129.2, 134.9, 136.4, 143.3, 144.2, 150.7, 156.7, 160.9, 163.8, 176.3; **HRMS (ESI)** 355.1176 ($C_{20}H_{20}O_6$) $[M+H]^+$ requires 355.1182. In agreement with literature[S7].

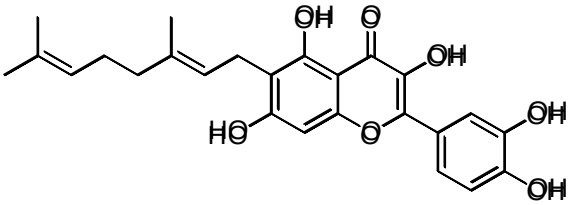
3,5,7-trihydroxy-6-(3-methylbut-2-en-1-yl)-2-(3,4,5-trihydroxyphenyl)-4H-chromen-4-one (3da)[S8]



Obtained from quercetin (302 mg, 1 mmol) and prenol (172 mg, 2 mmol). Yellow oil (196 mg, 53 %), R_f = 0.3 (Hexane: Ethyl acetate 2:1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 1.47 (s, 3H). 1.57 (s, 3H), 3.13 (d, *J* = 7.1 Hz, 2H), 5.11 (tt, J = 7.1, 1.3 Hz, 1H), 6.19 (d, J = 2.1 Hz, 1H), 6.30 (d, J = 2.1 Hz, 1H), 6.67 (s, 1H), 6.84 (s, 1H), 8.94 (s, 1H), 9.04 (s, 1H), 9.31 (s, 1H), 10.75 (s, 1H), 12.53 (s, 1H); **^{13}C NMR** (101 MHz, , DMSO-d_6) δ 17.5. 25.4, 31.2, 93.4, 98.2, 103.5, 116.5, 117.1, 120.3, 123.6, 131.0, 132.2, 136.4,

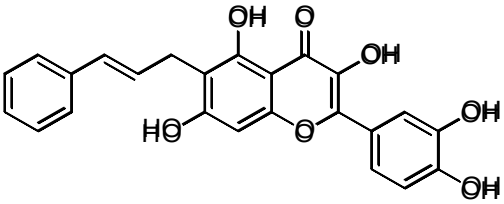
149.9, 147.1, 150.0, 156.7, 160.9, 163.8, 176.3; **HRMS (ESI)** 371.1129 ($C_{20}H_{19}O_7$) $[M+H]^+$ requires 371.1131). In agreement with literature[S8].

(E)-2-(3,4-dihydroxyphenyl)-6-(3,7-dimethylocta-2,6-dien-1-yl)-3,5,7-trihydroxy-4H-chromen-4-one (3db)



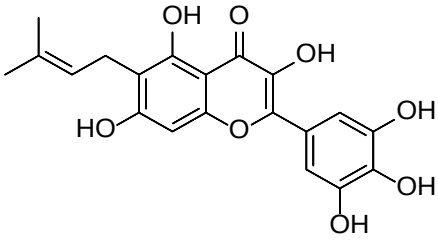
Obtained from quercetin (302 mg, 1 mmol) and geraniol (308 mg, 2 mmol). Yellow oil (285 mg, 65%), R_f = 0.15 (Hexane: Ethyl acetate 2:1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 1.47 (s, 3H). 1.52 (s, 3H), 1.17 (s, 3H), 2.01 (m, 4H), 3.35 (d, 2H), 5.00 (m, 1H), 5.39 (m, 1H), 6.15 (m, 1H), 6.41 (m, 1H), 6.91 (m, 1H), 7.66 (m, 2H), 9.38 (s, 1H), 9.67 (s, 1H), 10.77 (s, 1H), 12.44 (s, 1H); **^{13}C NMR** (101 MHz, , DMSO-d_6) δ 15.9, 17.5, 23.2, 25.5, 26.2, 31.4, 93.4, 98.2, 103.6, 116.7, 117.2, 120.4, 123.2, 124.1, 130.8, 132.4, 137.8, 136.4, 143.0, 147.2, 150.1, 156.8, 161.0, 163.9, 176.3; **HRMS (ESI)** 439.1752 ($C_{25}H_{27}O_7$) $[M+H]^+$ requires 439.1757.

6-cinnamyl-2-(3,4-dihydroxyphenyl)-5,7-dihydroxy-4H-chromen-4-one (3dc)



Obtained from quercetin (302 mg, 1 mmol) and cinnamyl alcohol (268 mg, 2 mmol). White solid (280 mg, 67%), m.p. 192.7-193.7 ºC, R_f = 0.21 (Hexane: Ethyl acetate 2:1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 3.66 (d, J = 6.1 Hz, 2H), 6.32 (s, 1H), 6.37 (m, 1H), 6.47 (d, J = 15.8 Hz, 1H), 6.89 (m, Hz, 1H), 7.16 (m, 2H), 7.24 (m, 3H), 7.32 (m, 2H), 7.60 (m, 1H), 7.76 (m, 1H), 9.37 (s, 1H), 9.39 (s, 1H), 9.60 (s, 1H), 10.82 (s, 1H), 12.47 (s, 1H); **^{13}C NMR** (101 MHz, , DMSO-d_6) δ 31.2, 93.4, 98.2, 103.5, 105.2, 116.5, 117.1, 120.3, 123.6, 128.0, 131.0, 132.2, 136.4, 142.9, 147.1, 150.0, 154.5, 156.7, 160.9, 163.8, 176.3; **HRMS (ESI)** 419.1125 ($C_{24}H_{19}O_7$) $[M+H]^+$ requires 419.1131.

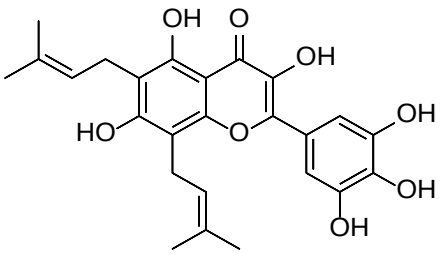
3,5,7-trihydroxy-6-(3-methylbut-2-en-1-yl)-2-(3,4,5-trihydroxyphenyl)-4H-chromen-4-one (3ea)



Obtained from myricetin (318 mg, 1 mmol) and prenol (172 mg, 2 mmol). White solid (96 mg, 24 %), m.p. 130.4-130.8 ºC, R_f = 0.2 (Hexane: Ethyl acetate 2:1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 1.33 (s, 3H), 1.47 (s, 3H), 3.14 (d, J = 6.8 Hz, 2H), 5.01 (t, J = 6.8 Hz, 1H), 6.18 (d, J = 2.0 Hz, 1H), 6.26 (d, J = 2.0 Hz, 1H), 6.42 (s, 1H), 8.40 (s, 1H), 8.76 (s, 1H), 8.85 (s, 1H), 9.23 (s,

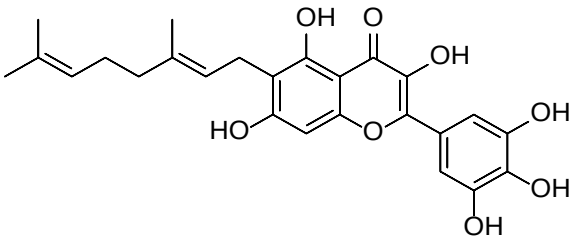
1H), 10.75 (s, 1H), 12.54 (s, 1H); **^{13}C NMR** (101 MHz, , DMSO-d_6) δ 17.9. 25.9, 26.2, 93.9, 98.7, 104.0, 108.9, 120.1, 120.8, 124.5, 129.7, 135.4, 136.9, 143.8, 144.8, 151.2, 157.2, 161.4, 164.3, 176.8; **HRMS (ESI)** 387.1081 ($C_{20}H_{19}O_8$) $[M+H]^+$ requires 387.1080.

3,5,7-trihydroxy-6,8-bis(3-methylbut-2-en-1-yl)-2-(3,4,5-trihydroxyphenyl)-4H-chromen-4-one (5ea)



Obtained from myricetin (318 mg, 1 mmol) and prenol (172 mg, 2 mmol). Brown solid (286 mg, 63 %), m.p. 149.8-150.5 ºC, R_f = 0.18 (Hexane: Ethyl acetate 2:1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 1.23 (s, 6H), 1.41 (s, 6H), 3.05 (m, 4H), 4.95 (m, 2H), 6.18 (d, *J* = 2.0 Hz, 1H), 6.22 (d, *J* = 2.0 Hz, 1H), 8.25 (s, 2H), 8.58 (s, 1H), 8.86 (s, 1H), 10.81 (s, 1H), 12.54 (s, 1H); **^{13}C NMR** (101 MHz, , DMSO-d_6) δ 17.2, 25.4, 25.9, 93.3, 98.1, 103.7, 119.9, 120.9, 123.8, 128.9, 135.6, 137.4, 141.9, 150.1, 157.1, 160.9, 163.8, 176.4; **HRMS (ESI)** 455.1700 ($C_{25}H_{27}O_8$) $[M+H]^+$ requires 455.1706.

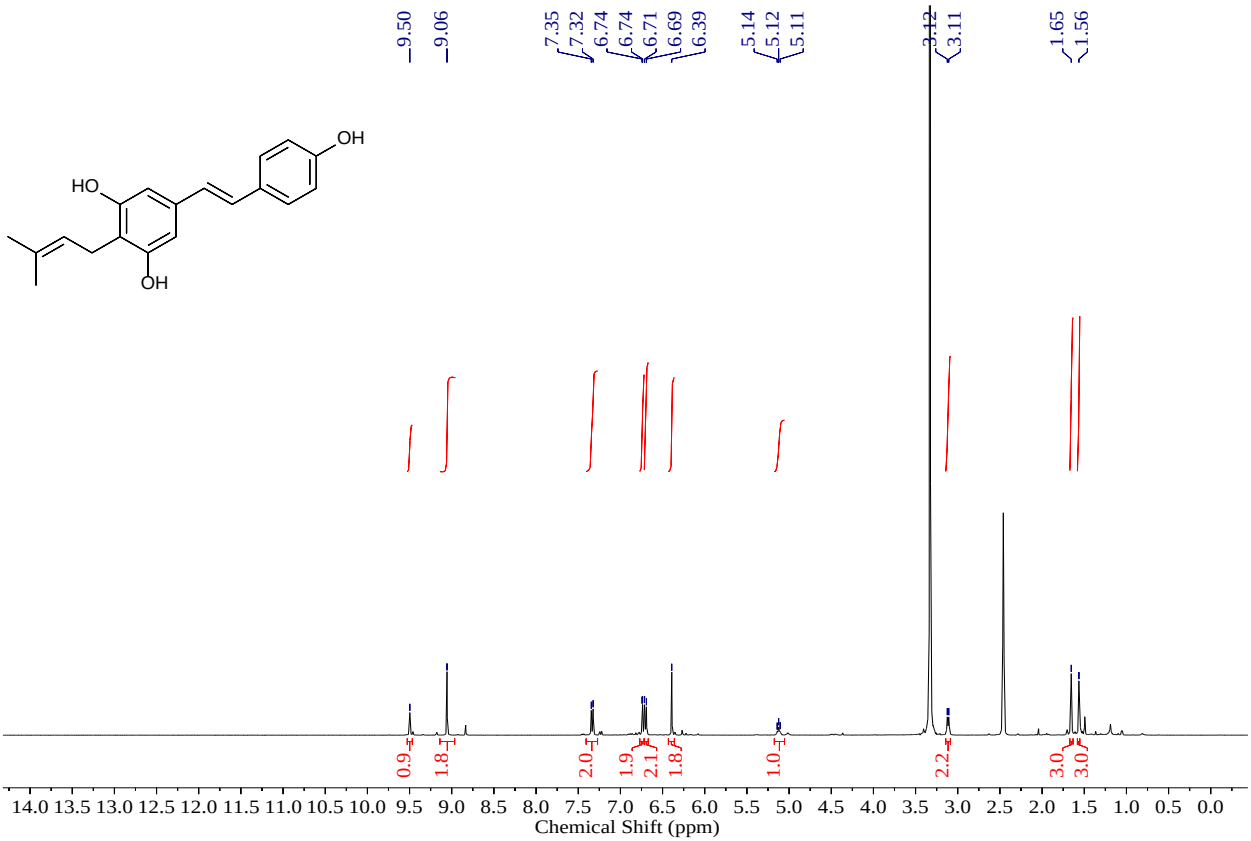
(E)-6-(3,7-dimethylocta-2,6-dien-1-yl)-3,5,7-trihydroxy-2-(3,4,5trihydroxy-phenyl)-4H-chromen-4-one (3eb)



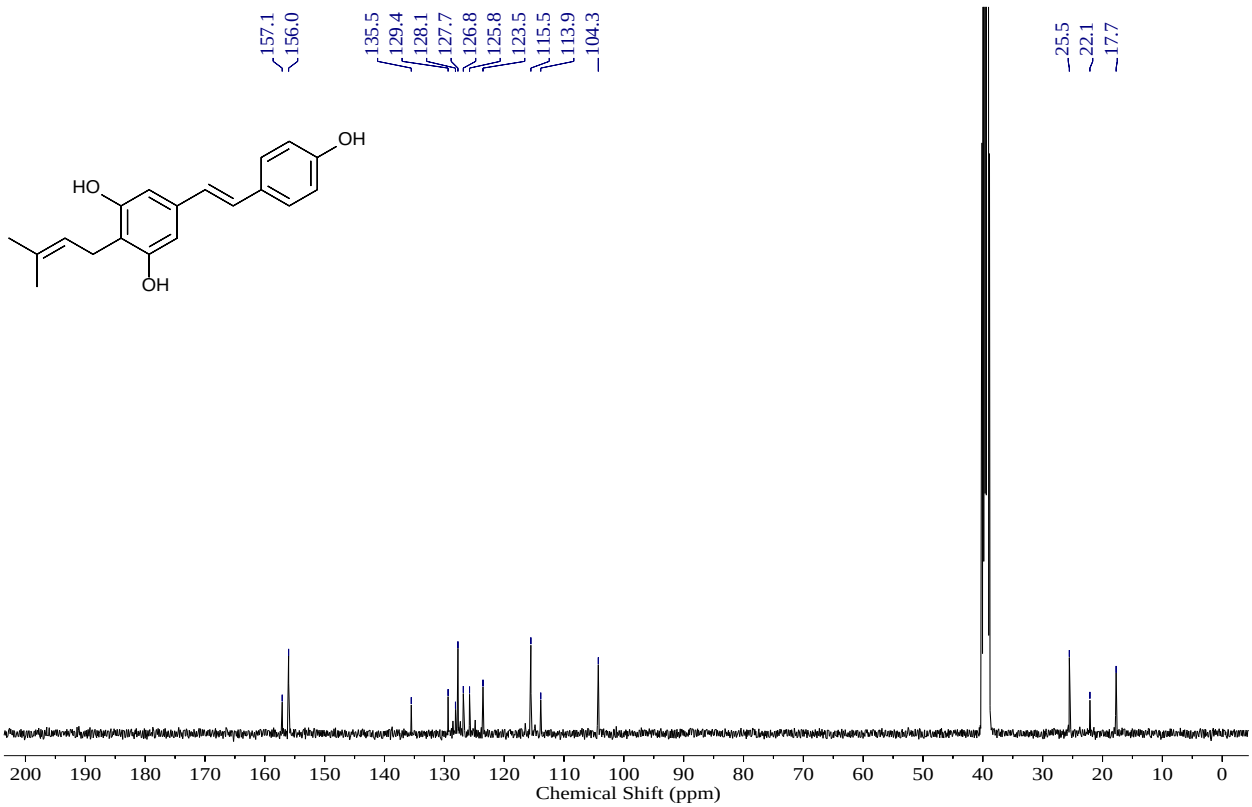
Obtained from myricetin (318 mg, 1 mmol) and geraniol (308 mg, 2 mmol). White solid (331 mg, 73 %), m.p. 139.8-140.2 ºC, R_f = 0.16 (Hexane: Ethyl acetate 2:1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 1.33 (s, 3H), 1.46 (s, 3H), 1.57 (s, 3H), 1.74 (m, 4H), 3.05 (m, 4H), 3.20 (d, *J* = 6.7 Hz, 2H), 4.95 (m, 2H), 6.17 (d, *J* = 2.0 Hz, 1H), 6.25 (d, *J* = 2.0 Hz, 1H), 6.43 (s, 1H), 8.40 (s, 1H), 8.77 (s, 1H), 8.85 (s, 1H), 9.23(s, 1H), 10.72 (s, 1H), 12.54 (s, 1H); **^{13}C NMR** (126 MHz, , DMSO-d_6) δ 15.8, 17.5, 25.2, 25.5, 26.1, 93.3, 98.1, 103.5, 108.5 119.7, 120.4, 123.5, 124.5, 130.6, 133.1, 134.9, 136.3, 143.3, 144.2, 150.7, 156.7, 160.9, 163.8, 176.3.; **HRMS (ESI)** 455.1701 ($C_{25}H_{27}O_8$) $[M+H]^+$ requires 455.1706.

8. ^{1}H and ^{13}C-NMR Spectra

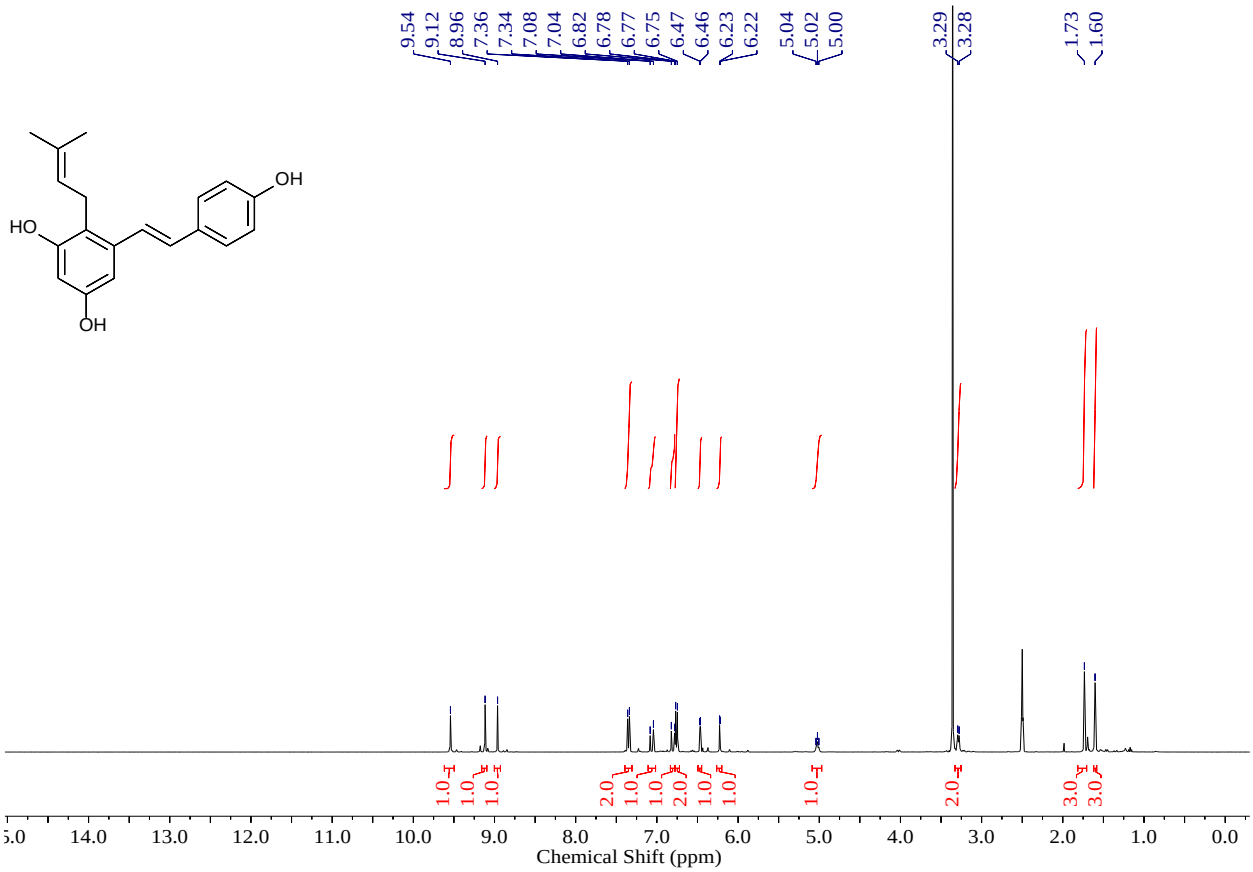
^{1}H NMR, 3aa (400 MHz, DMSO)



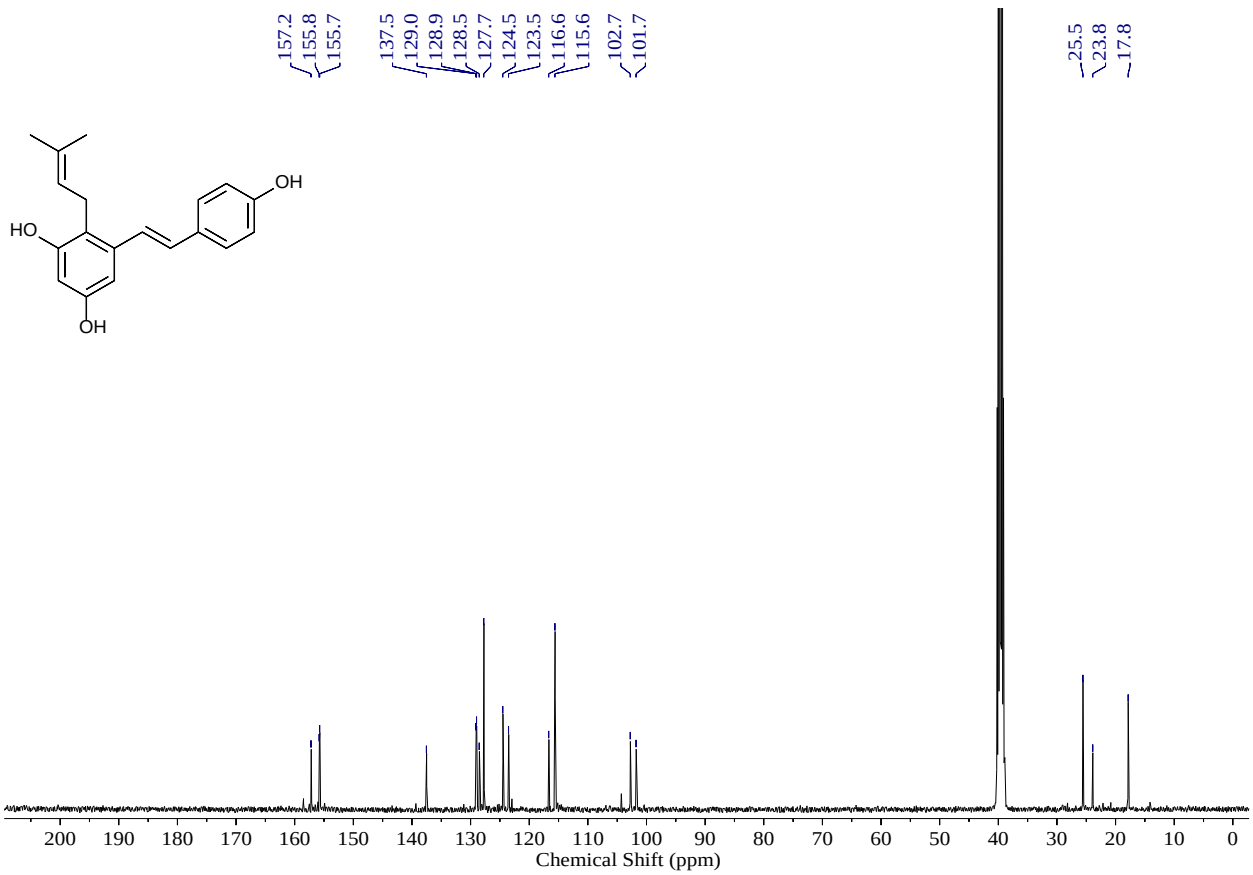
^{13}C NMR, 3aa (100 MHz, DMSO)



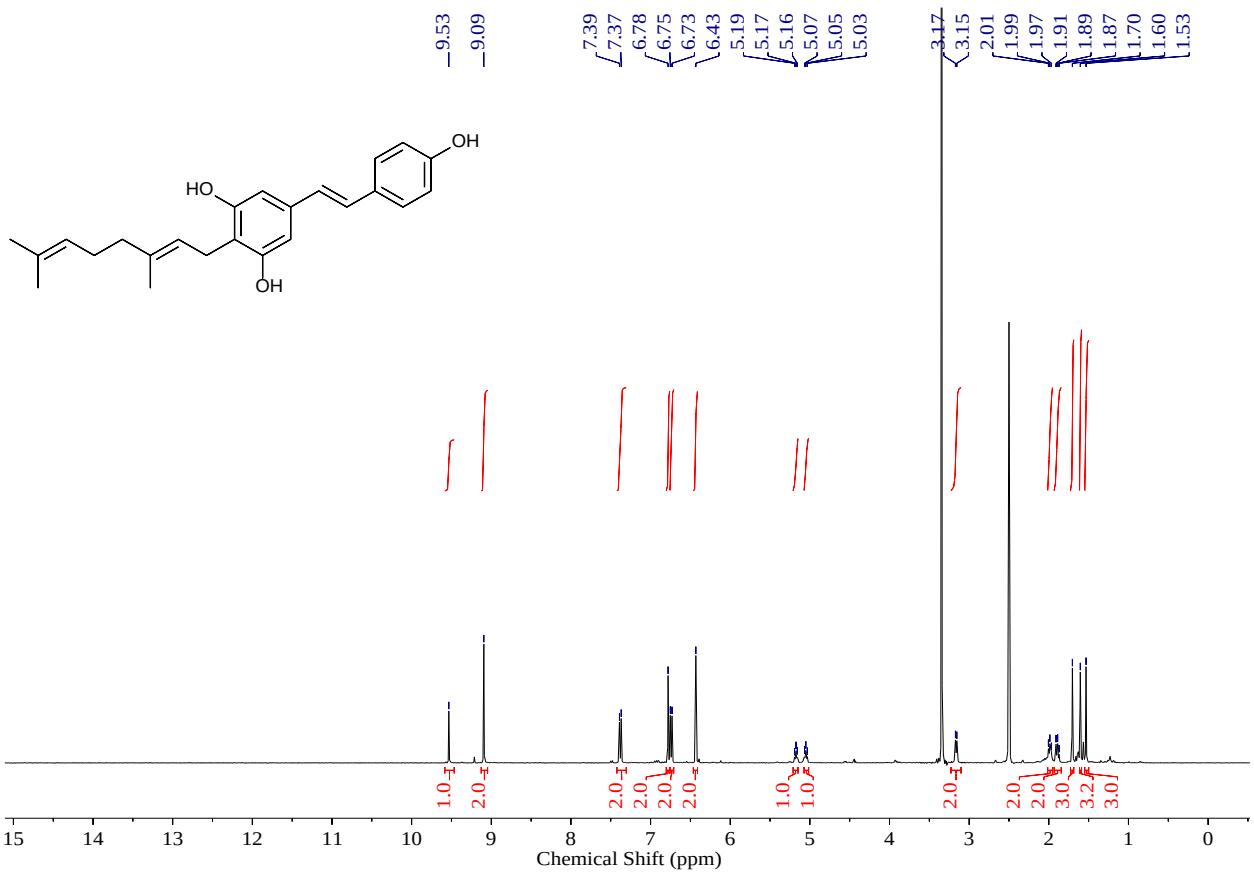
^{1}H NMR, 4aa (400 MHz, DMSO)



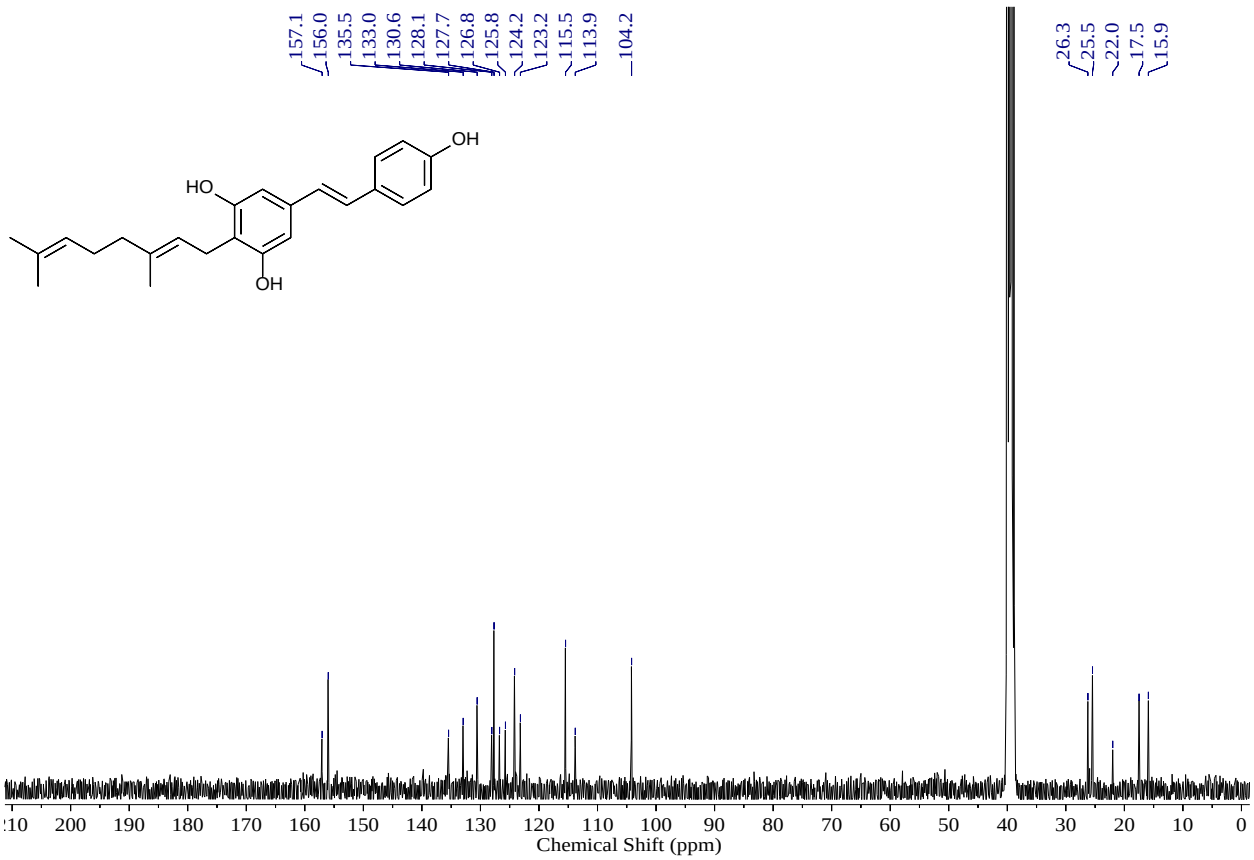
^{13}C NMR, 4aa (100 MHz, DMSO)



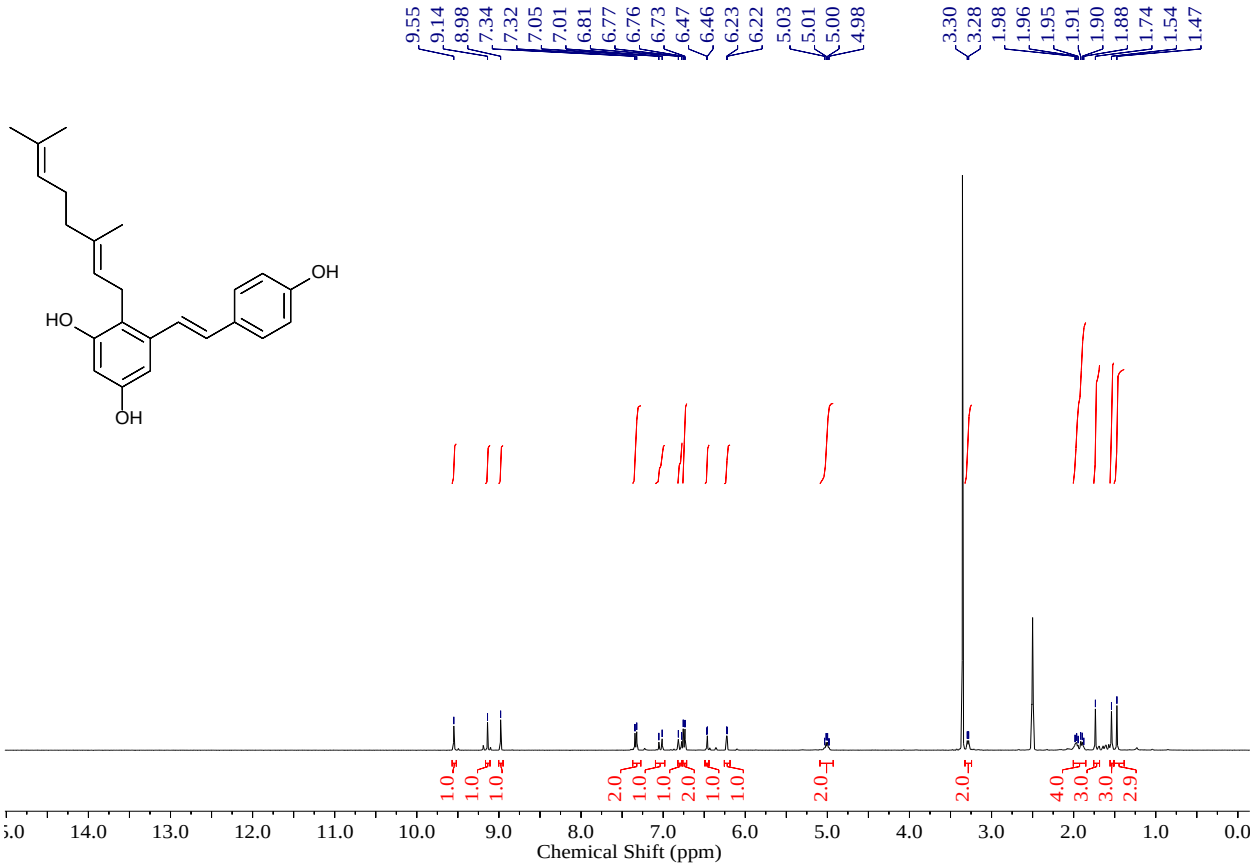
^{1}H NMR, 3ab (400 MHz, DMSO)



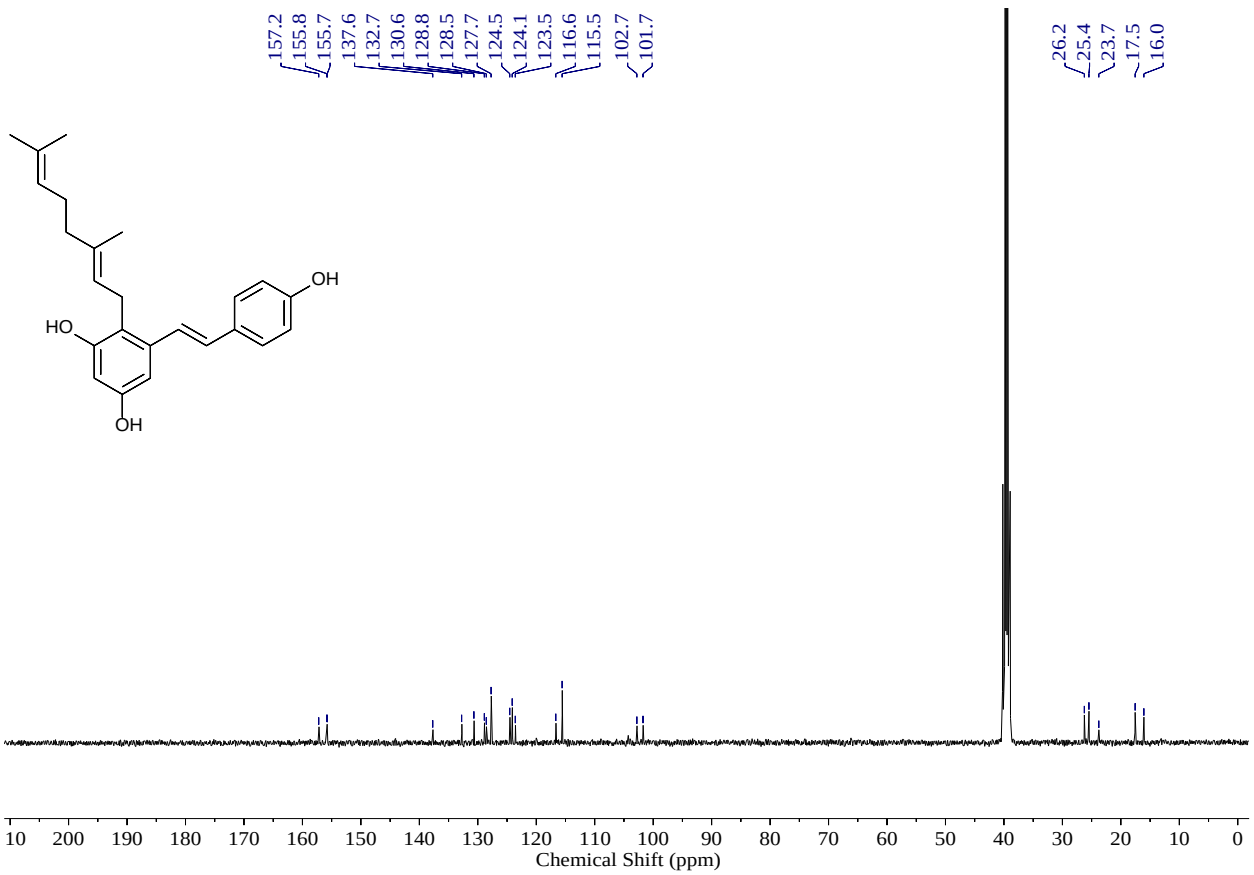
^{13}C NMR, 3ab (100 MHz, DMSO)



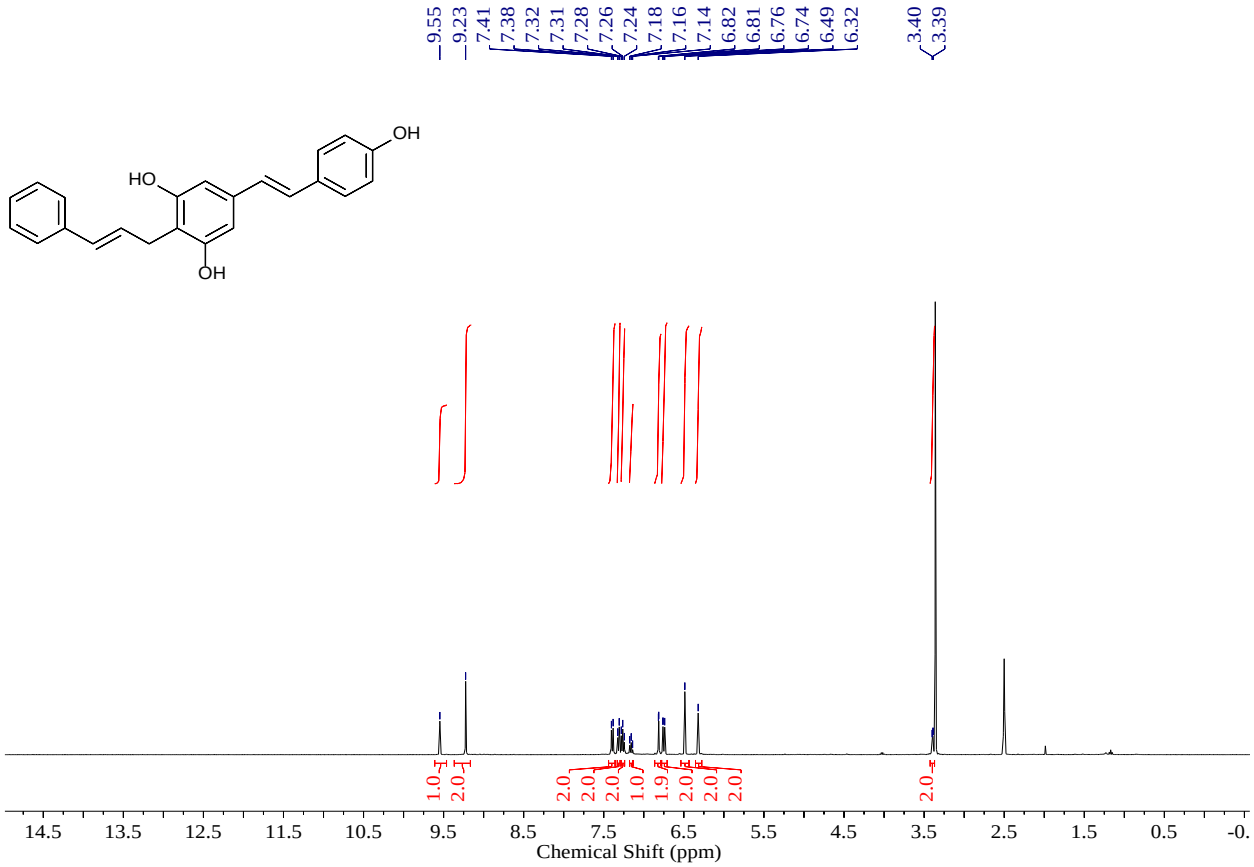
^{1}H NMR, 4ab (400 MHz, DMSO)



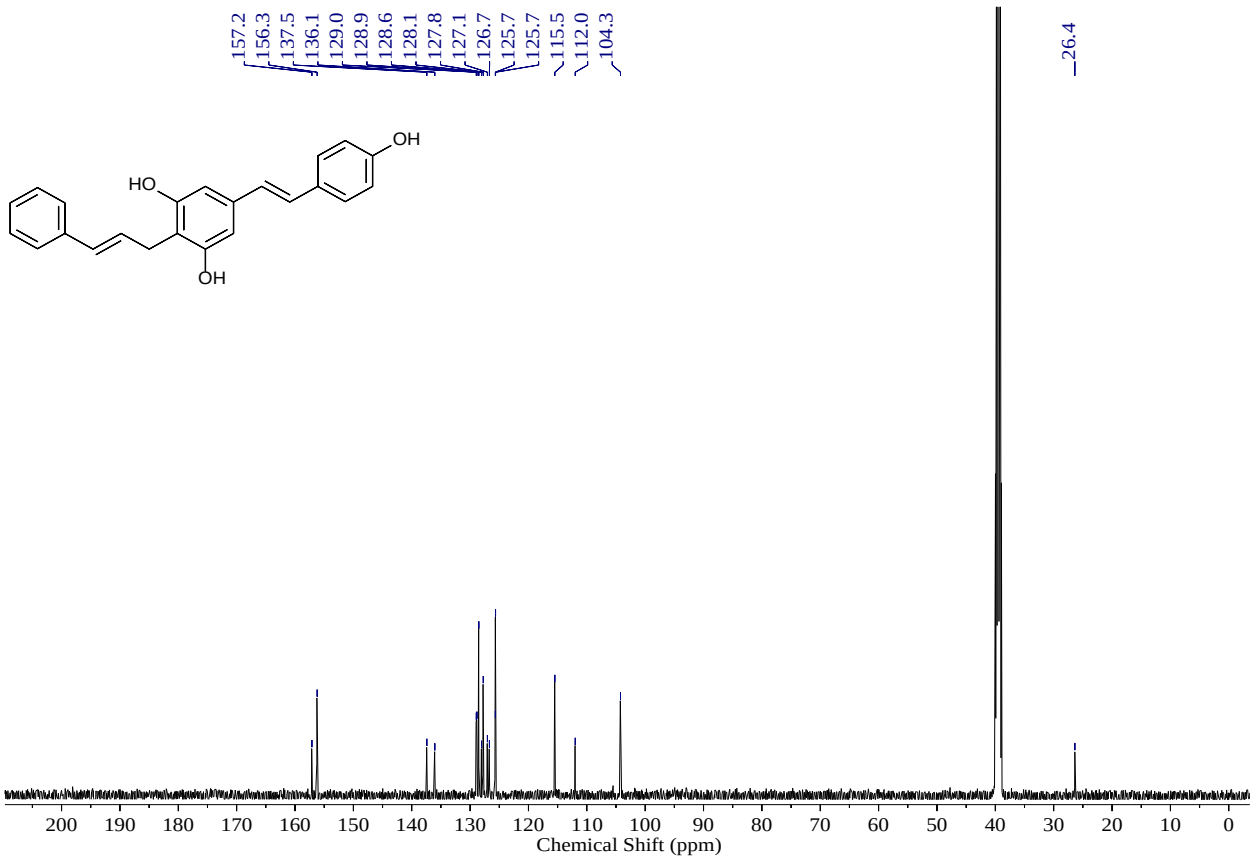
^{13}C NMR, 4ab (100 MHz, DMSO)



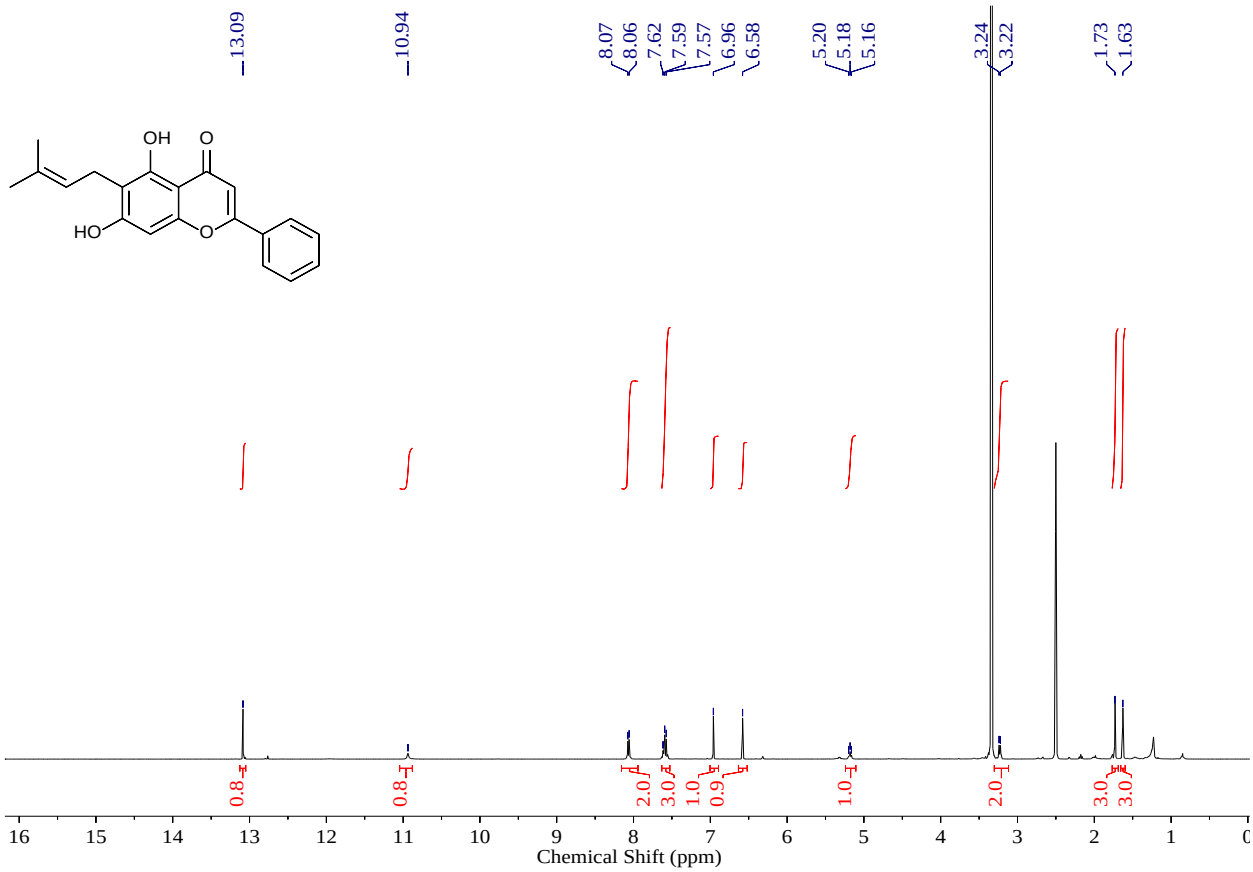
^{1}H NMR, 3ac (400 MHz, DMSO)



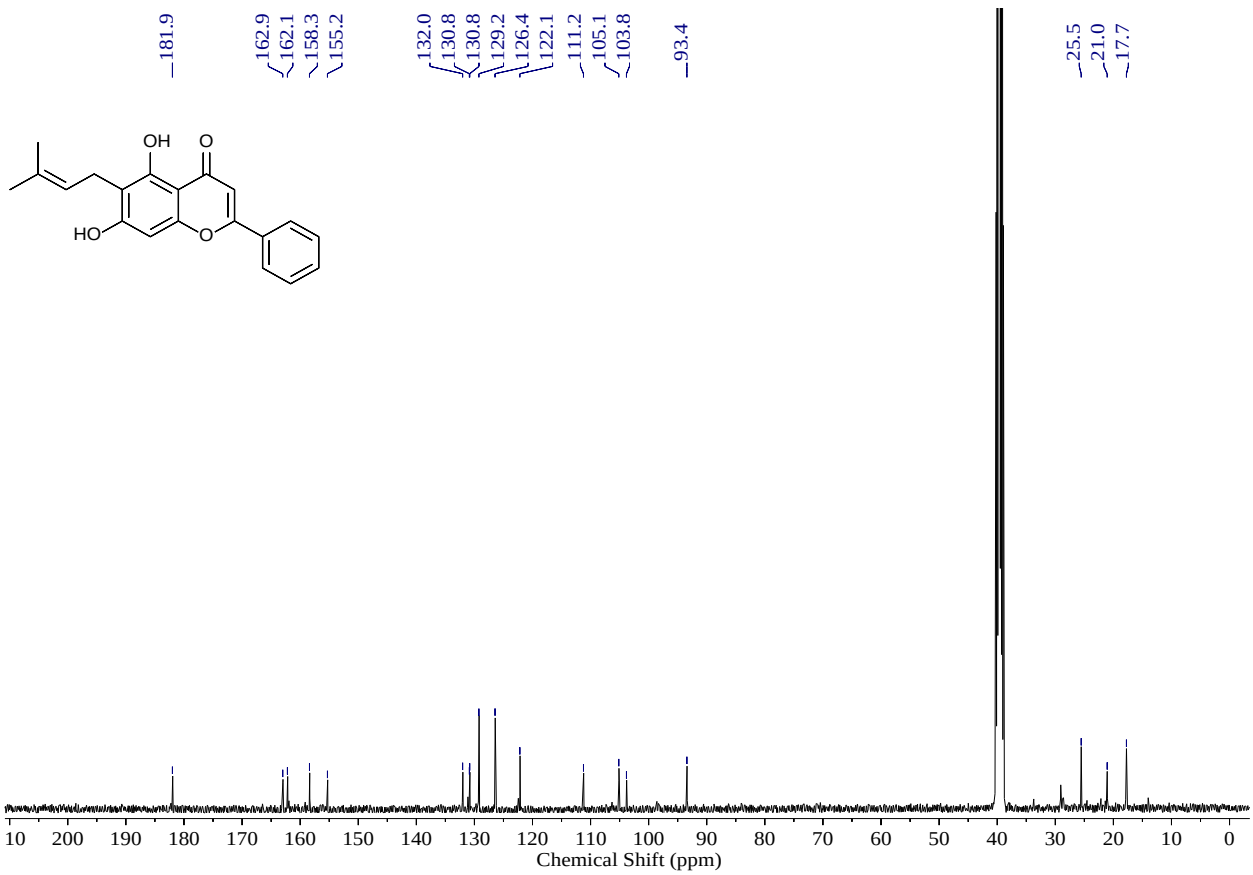
^{13}C NMR, 3ac (126 MHz, DMSO)



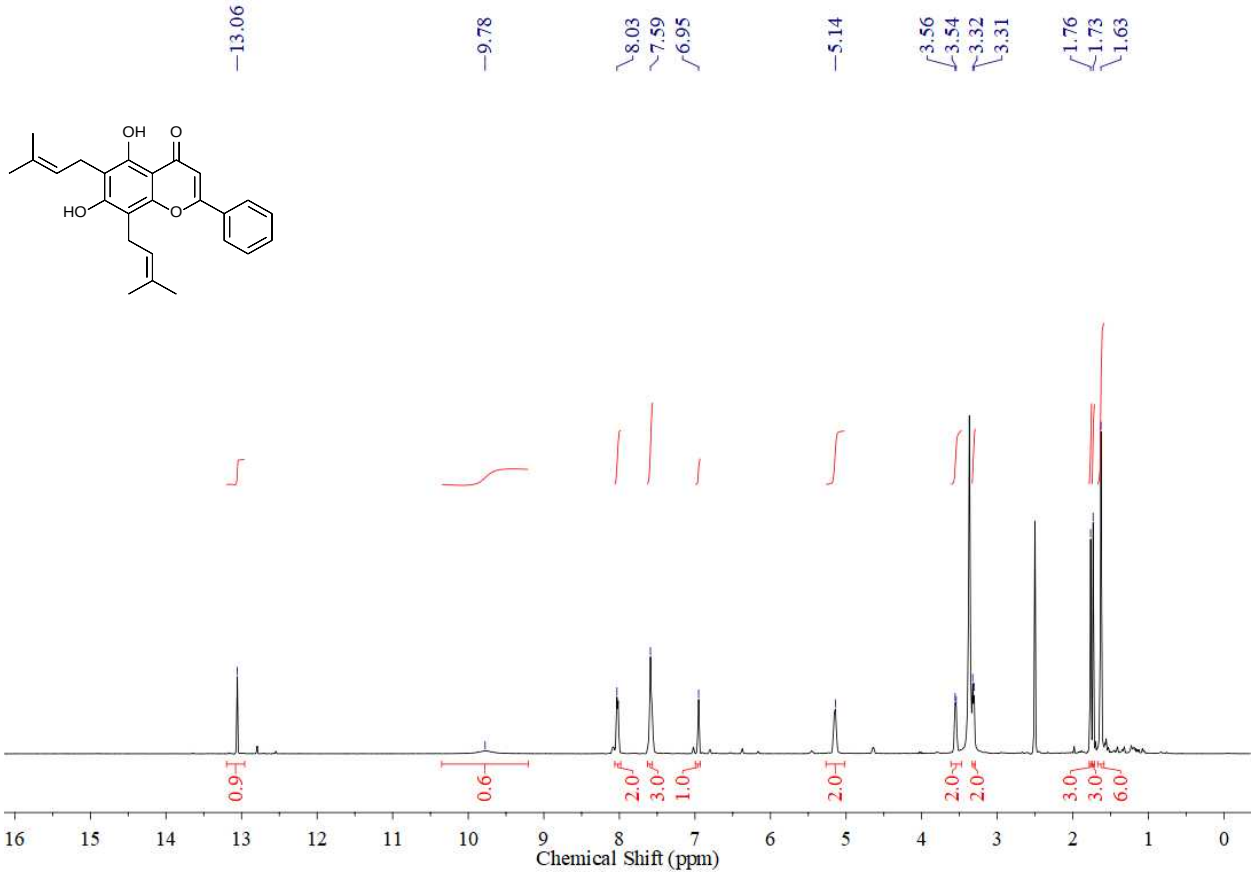
^{1}H NMR, 3ba (400 MHz, DMSO)



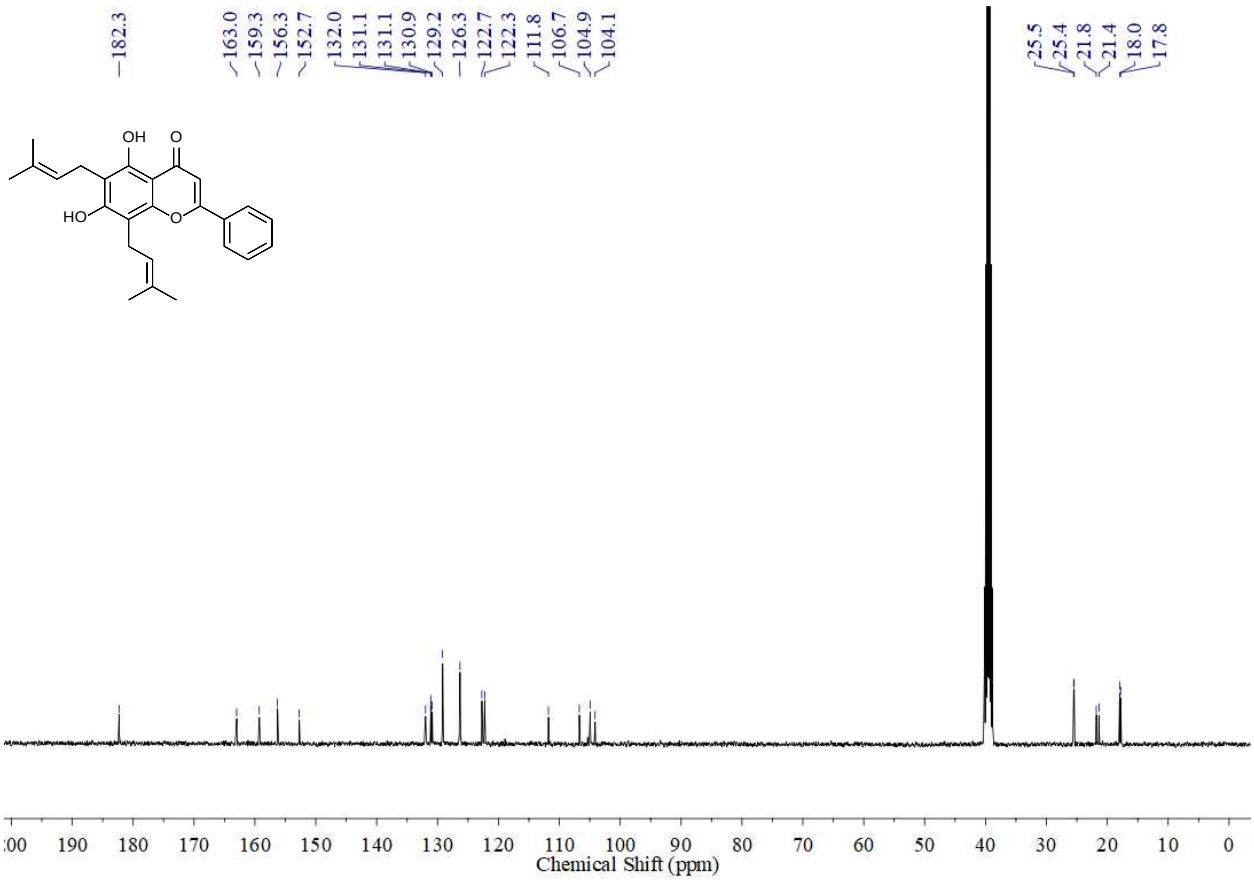
^{13}C NMR, 3ba (126 MHz, DMSO)



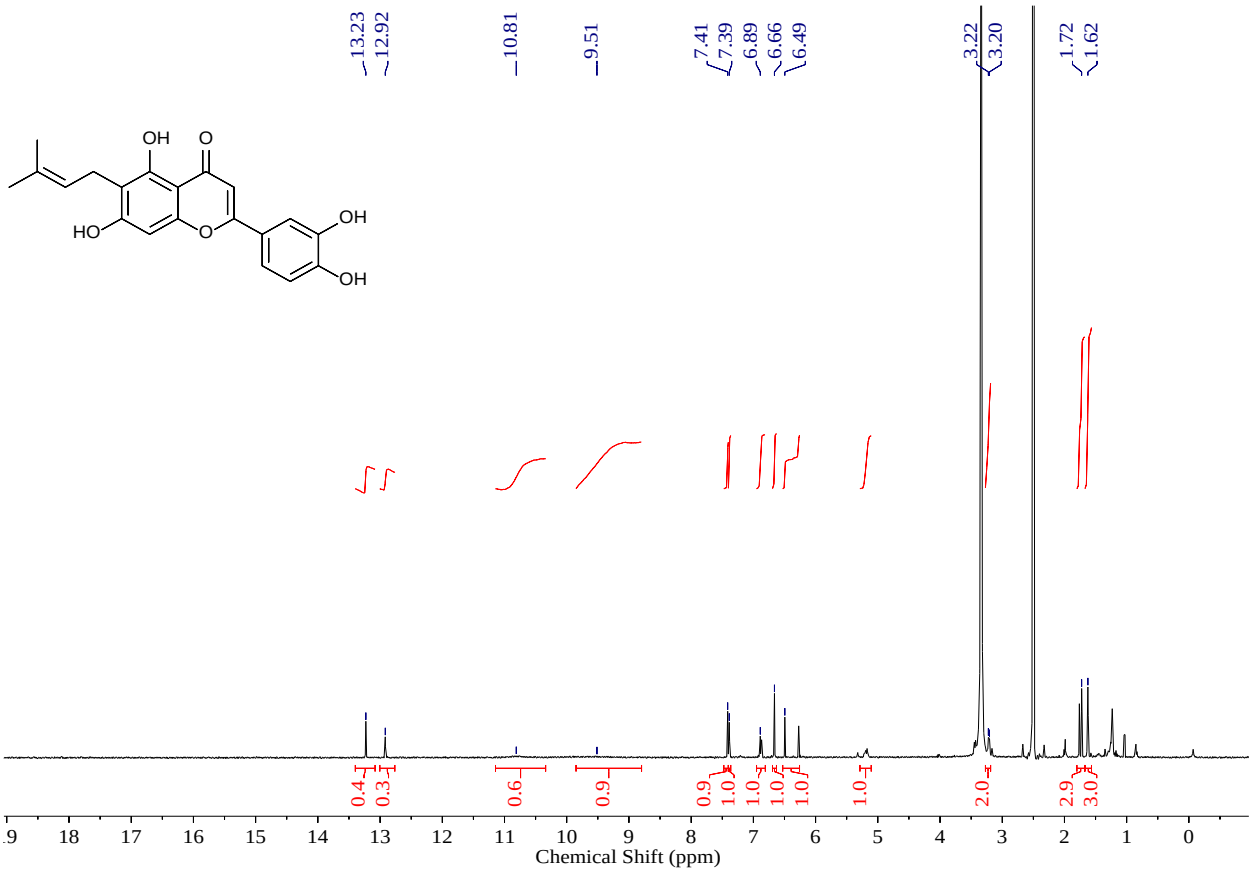
^{1}H NMR, 5ba (400 MHz, DMSO)



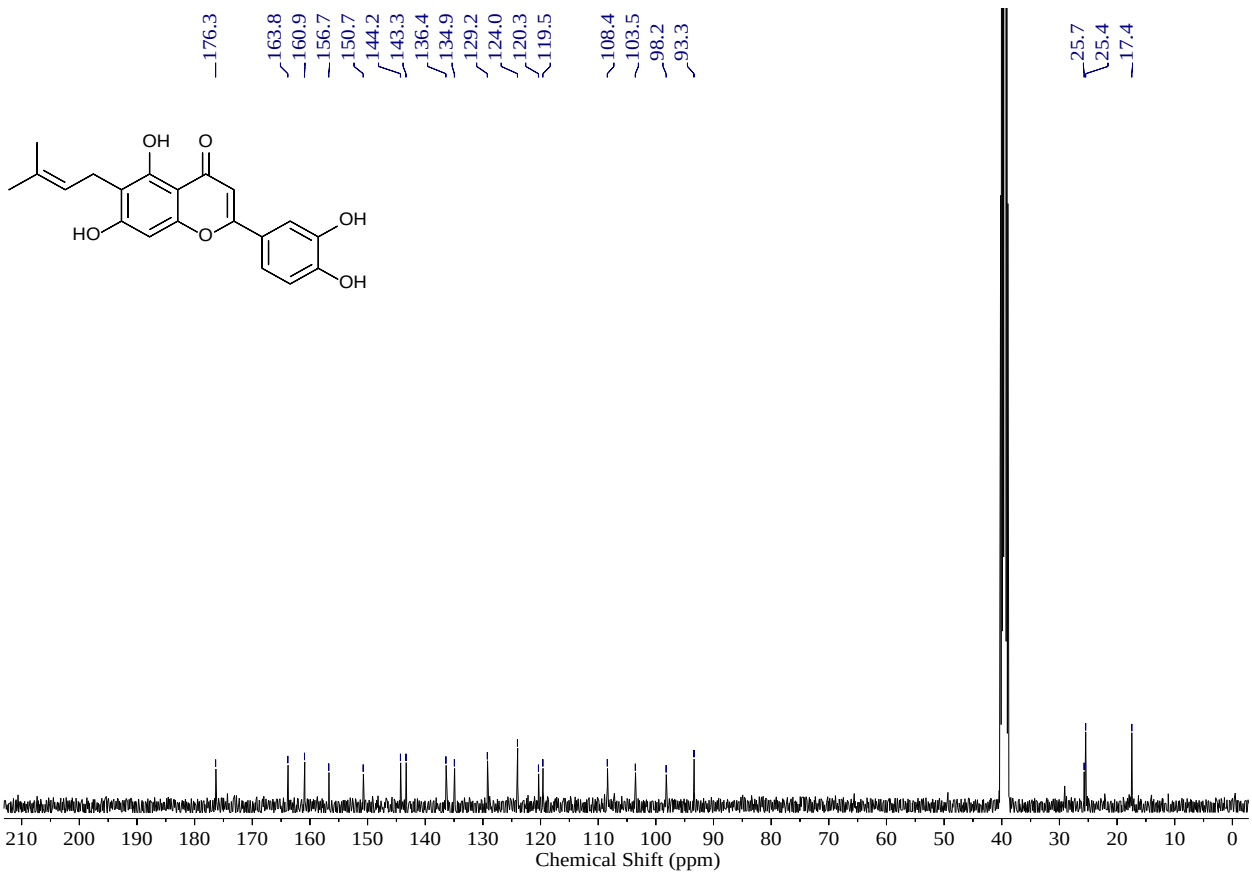
^{13}C NMR, 5ba (101 MHz, DMSO)



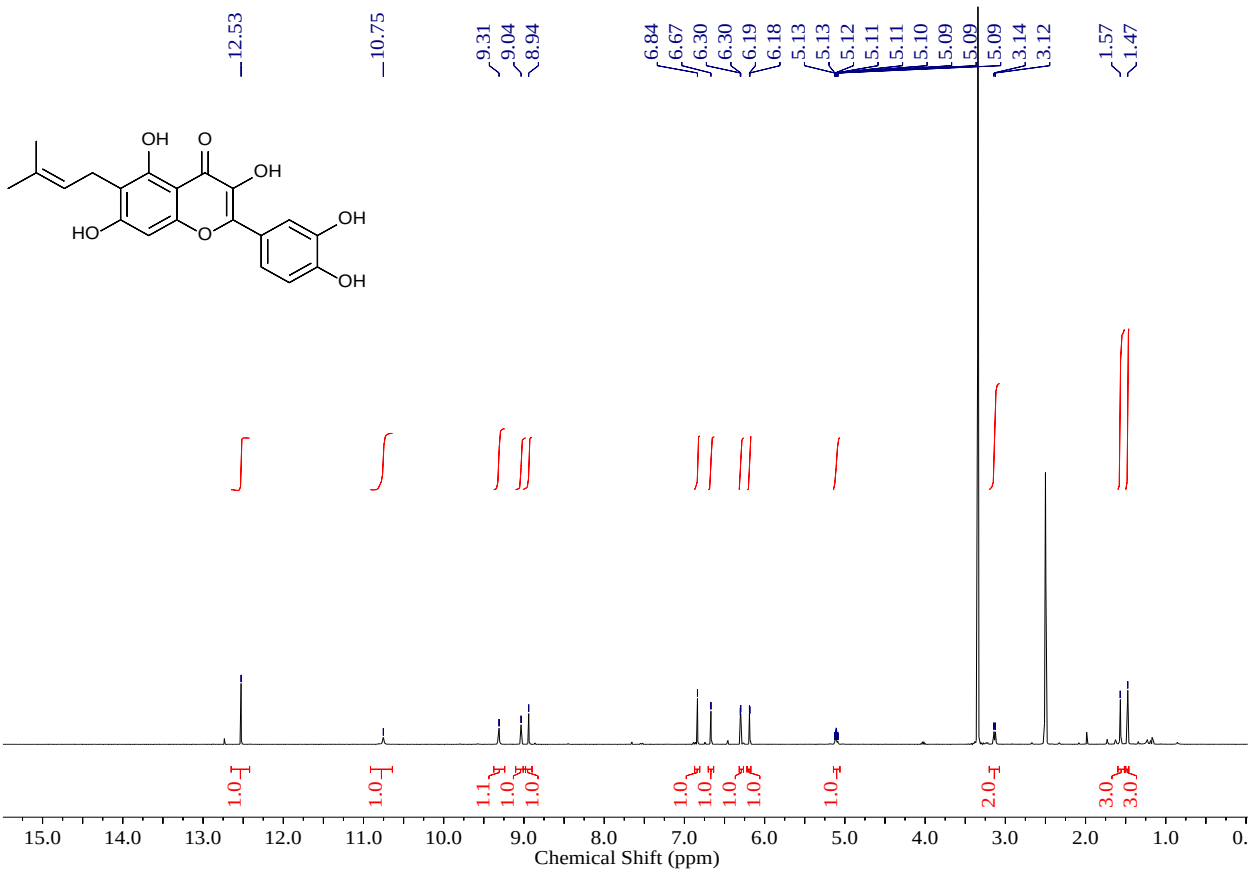
^{1}H NMR, 3ca (400 MHz, DMSO)



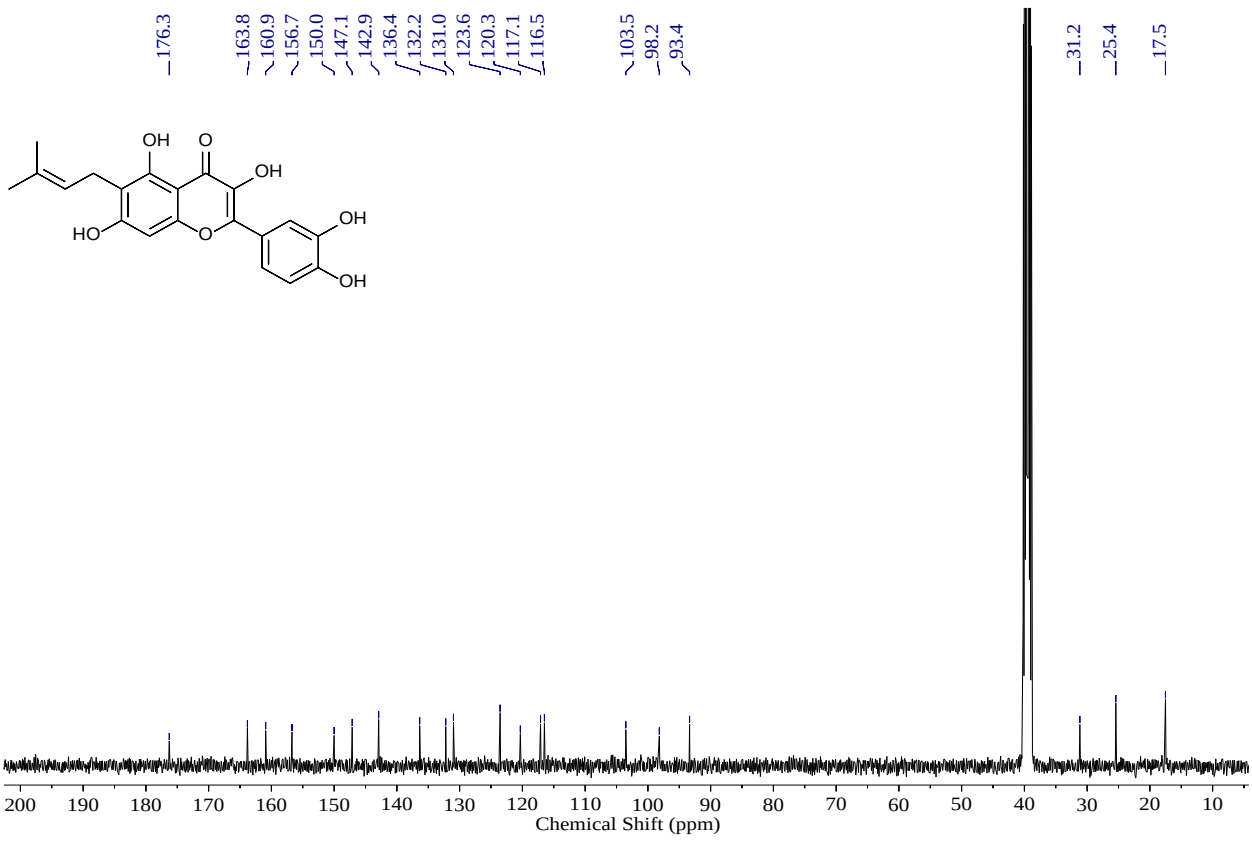
^{13}C NMR, 3ca (101 MHz, DMSO)



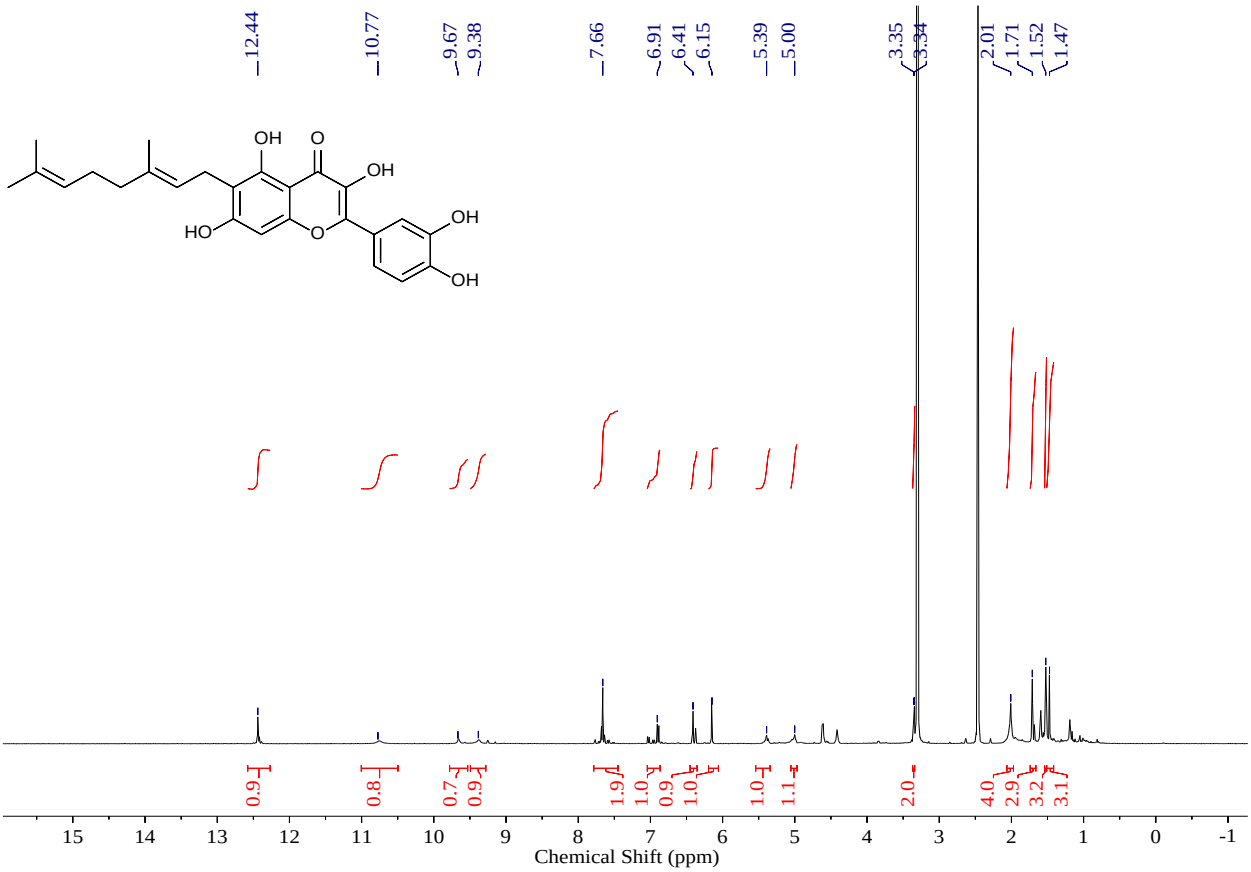
^{1}H NMR, 3da (400 MHz, DMSO)



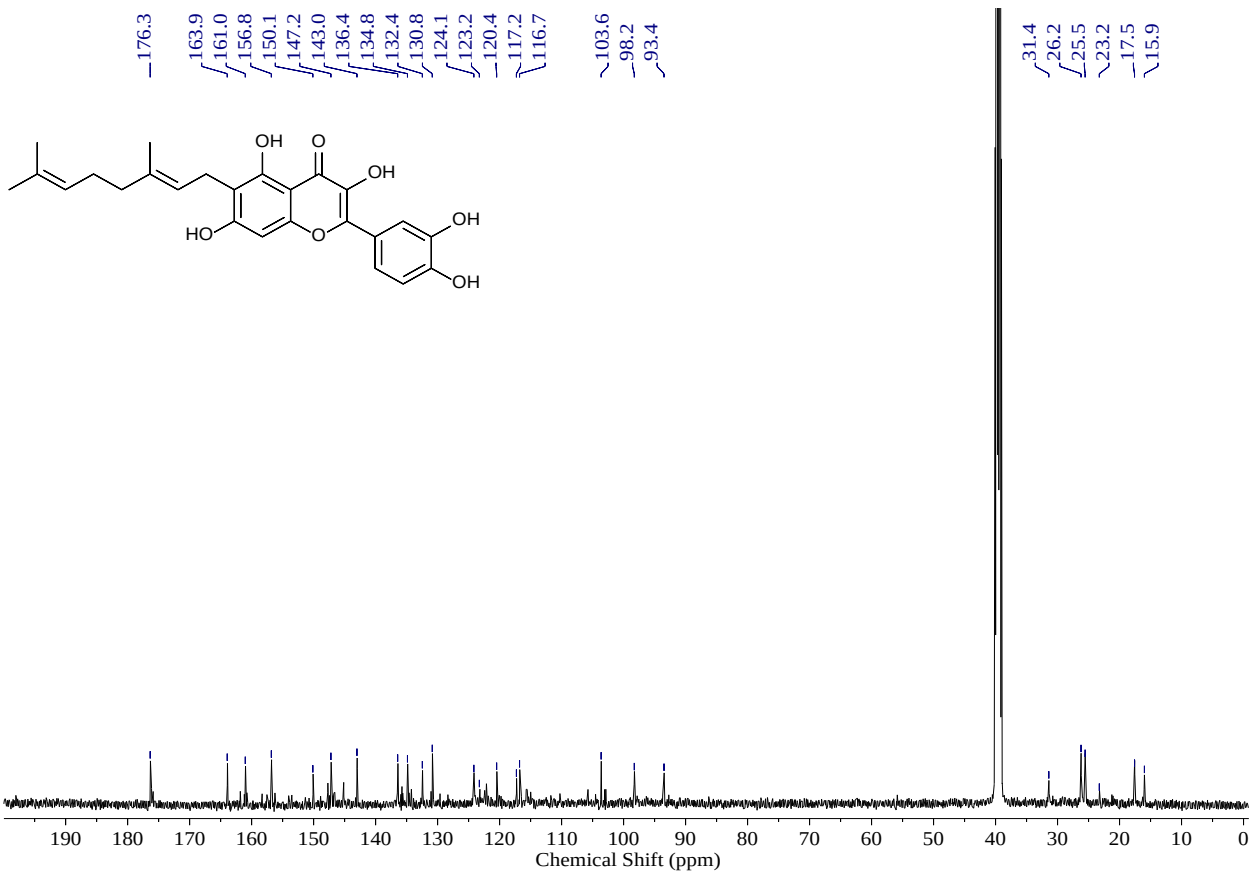
^{13}C NMR, 3da (101MHz, DMSO)



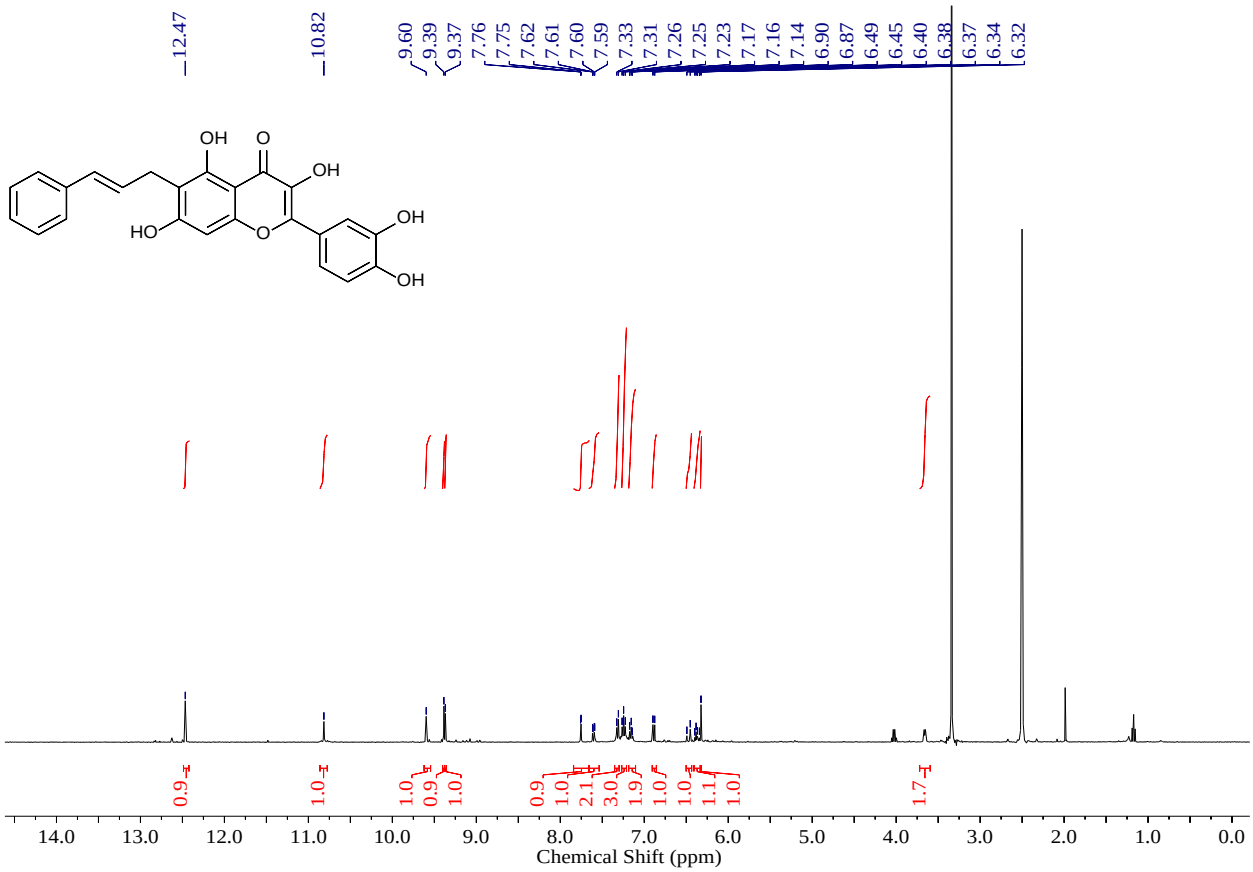
^{1}H NMR, 3db (400 MHz, DMSO)



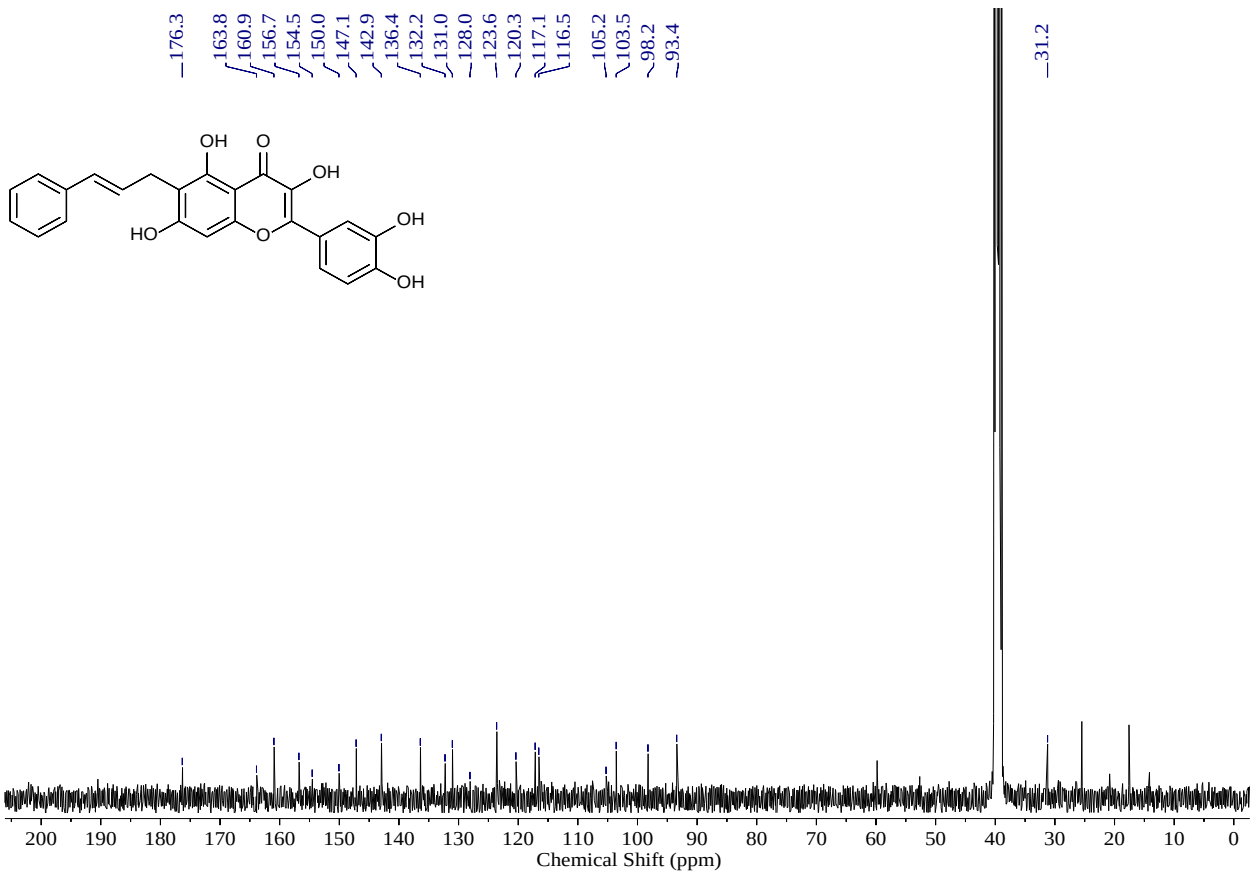
^{13}C NMR, 3db (126 MHz, DMSO)



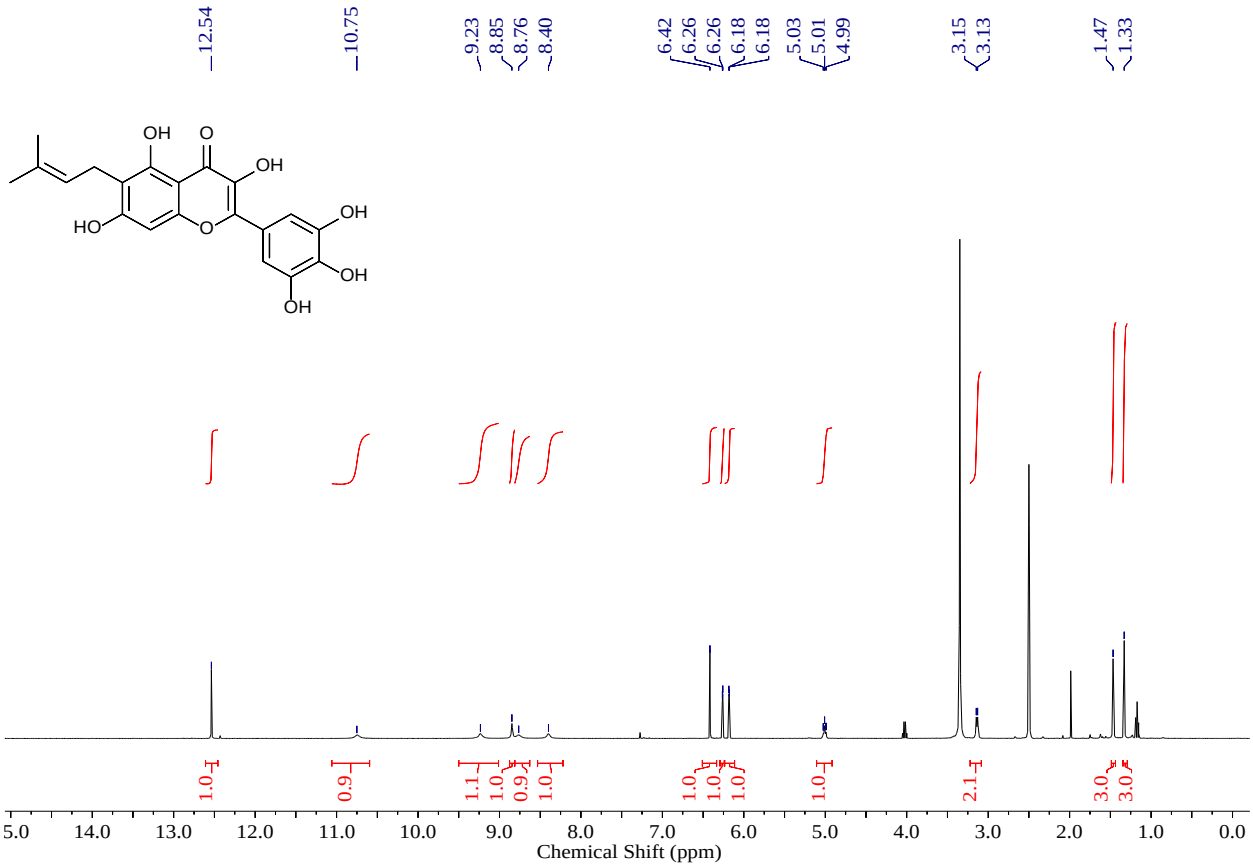
^{1}H NMR, 3dc (500 MHz, DMSO)



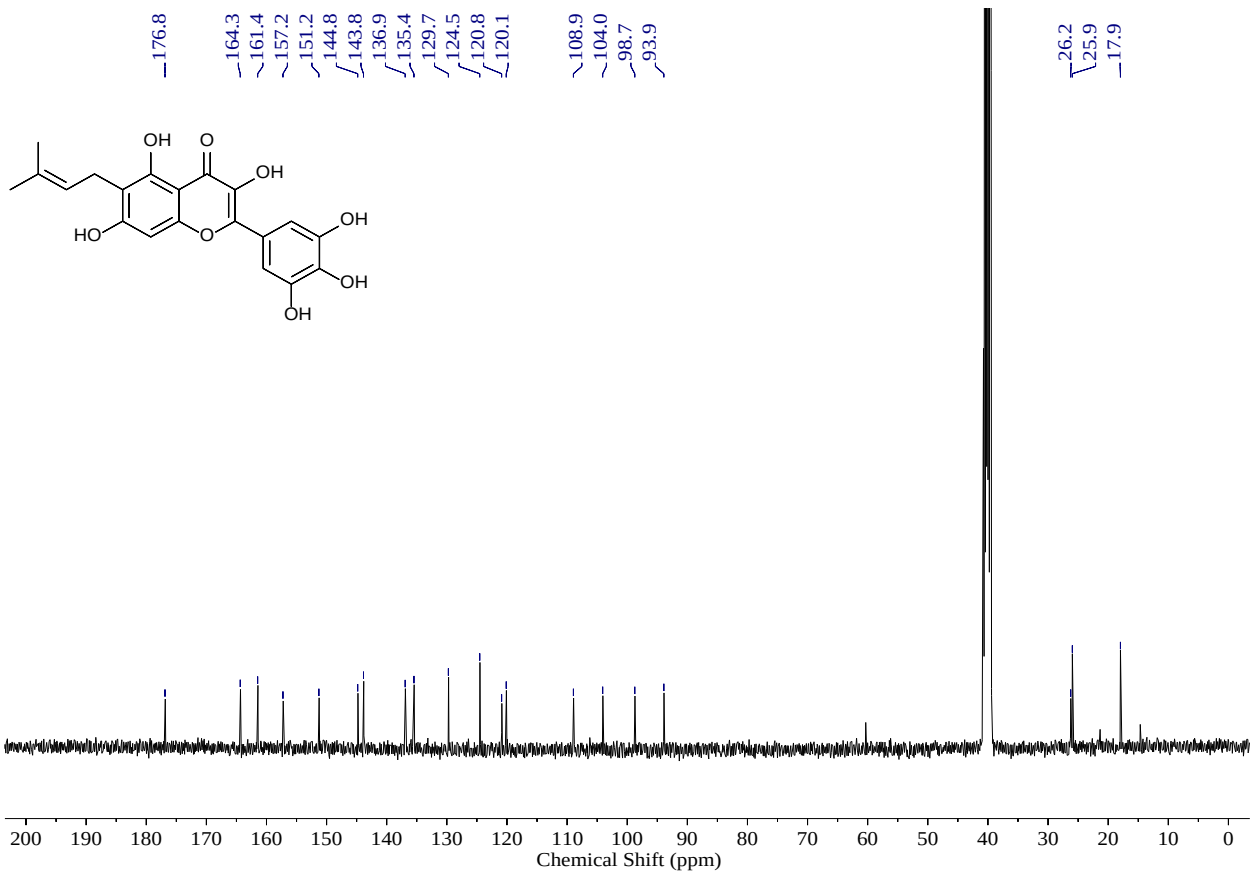
^{13}C NMR, 3dc (126 MHz, DMSO)



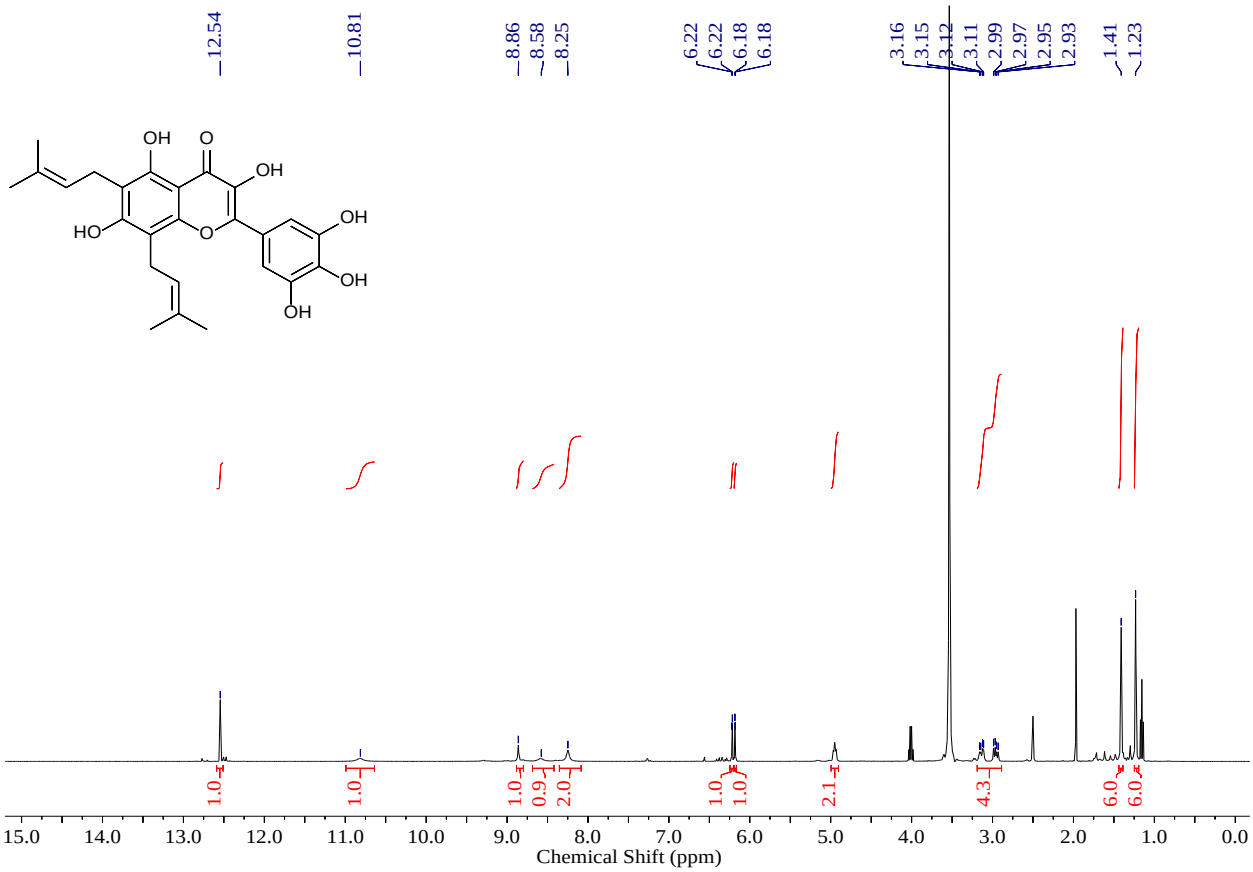
^{1}H NMR, 3ea (400 MHz, DMSO)



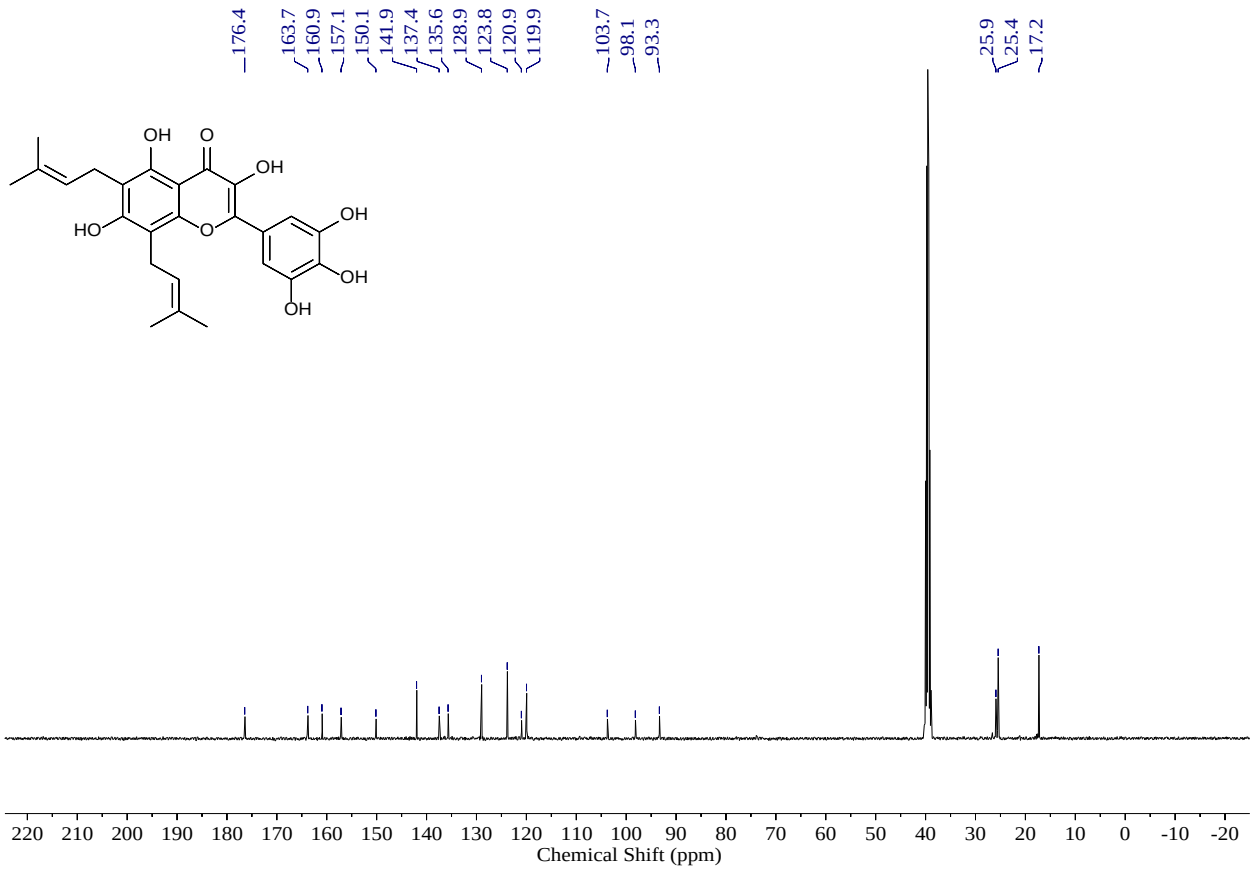
^{13}C NMR, 3ea (101 MHz, DMSO)



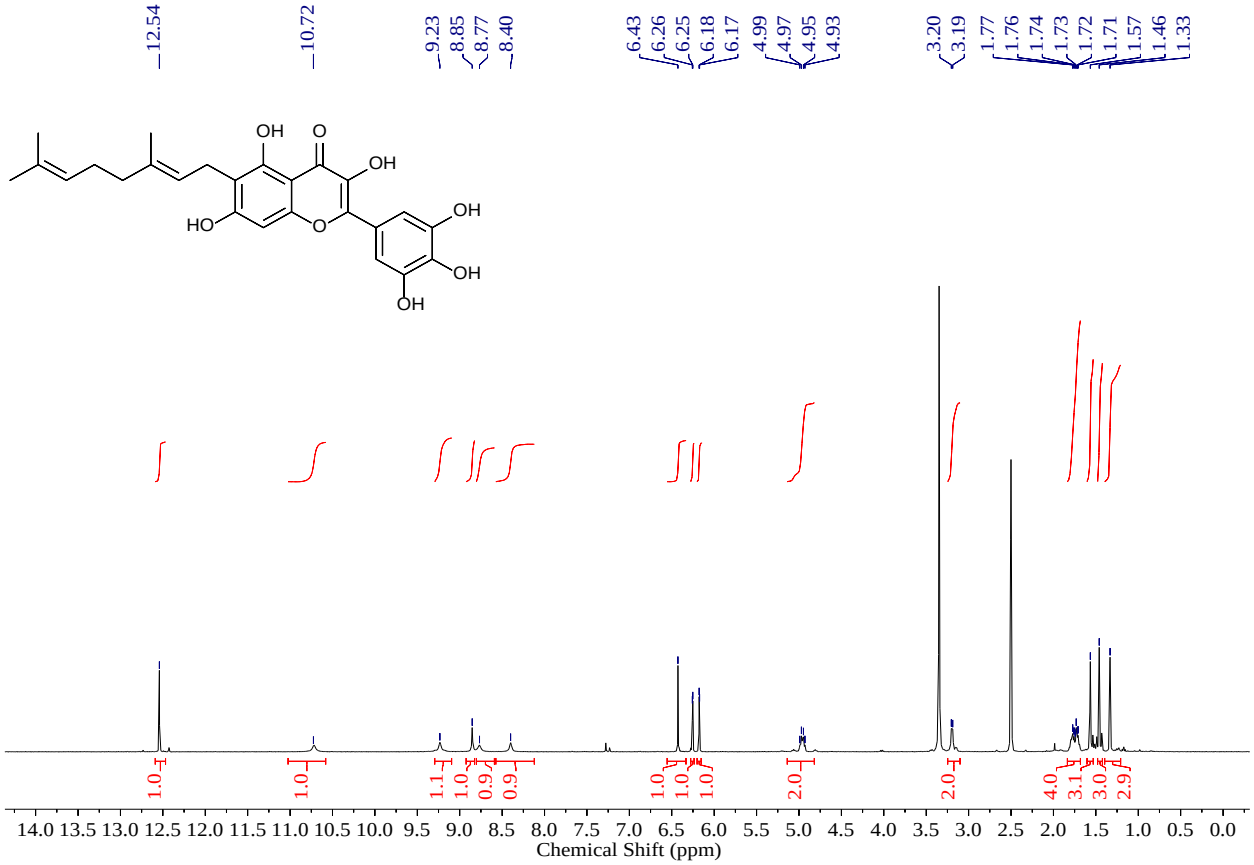
^{1}H NMR, 5ea (400 MHz, DMSO)



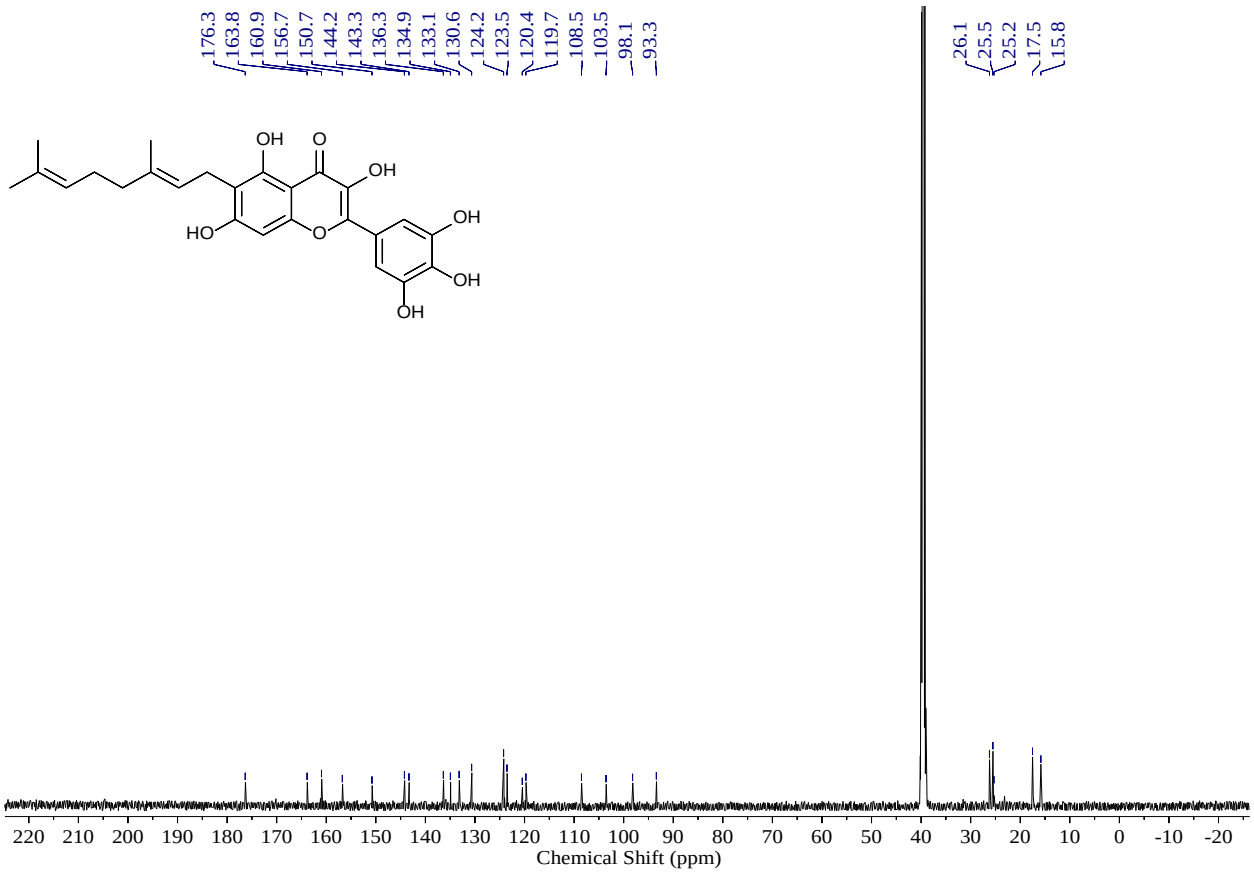
^{13}C NMR, 5ea (101 MHz, DMSO)



^{1}H NMR, 5ea (400 MHz, DMSO)



^{13}C NMR, 5ea (101 MHz, DMSO)



References

S1. Y.-W. Tang, C.-J. Shi, H.-L. Yang, P. Cai, Q.-H. Liu, X.-L. Yang, L.-Y. Kong and X.-B. Wang, *Euro. J. Med. Chem.*, 2019, **163**, 307-319.

S2. C. C. Duke, V. H. Tran, R. K. Duke, A. Abu-Mellal, G. T. Plunkett, D. I. King, K. Hamid, K. L. Wilson, R. L. Barrett and J. J. Bruhl, *Phytochem.*, 2017, **134**, 87-97.

S3. S. Bo, S. K. Chang, T. Zhou, H. Zhu, Y. Jiang and B. Yang, *Food Chem.*, 2022, **378**, 132118.

S4. B. H. Park, H. J. Lee and Y. R. Lee, *J. .Nat. Prod.*, 2011, **74**, 644-649.

S5. M. Tanjung, L. D. Juliawaty, E. H. Hakim and Y. M. Syah, *Fitoterapia*, 2018, **126**, 74-77.

S6. G. Comte, J.-B. Daskiewicz, C. Bayet, G. Conseil, A. Viornery-Vanier, C. Dumontet, A. Di Pietro, D. Barron, *J. Med. Chem*. 2001. **44**, 763-768.

S7. M. Osorio, M. Carvajal, A. Vergara, E. Butassi, S. Zacchino, C. Mascayano, M. Montoya, S. Mejías, M. C.-S. Martín and Y. Vásquez-Martínez, *Int. J. Mol. Sci.*, 2021, **22**, 5472.

S8. W. Li, L. Shu, K. Liu and Q. Wang, *Tetrahedron Lett.*, 2019, **60**, 151138.