Supporting Information

Green Knoevenagel: Pyridine and Piperidine-free Condensation of Benzaldehydes

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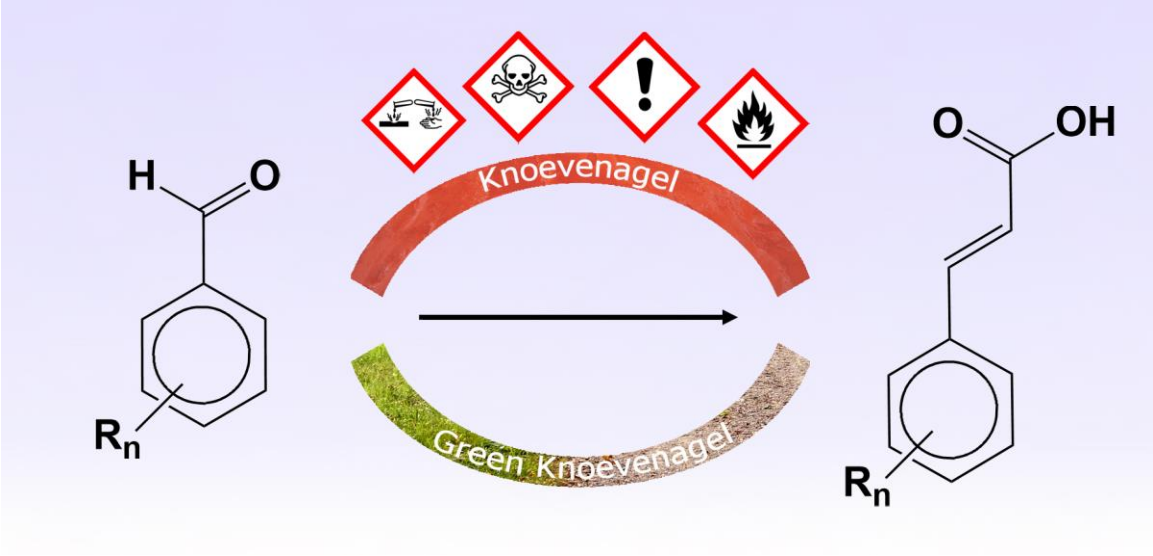


CAS Registry Numbers for Compounds

Compound		CAS Registry No.	IUPAC name
syringaldehyde	**1a**	134-96-3	4-hydroxy-3,5-dimethoxybenzaldehyde
benzaldehyde	**1b**	100-52-7	benzaldehyde
p-tolualdehyde	**1c**	104-87-0	4-methylbenzaldehyde
4-nitrobenzaldehyde	**1d**	555-16-8	4-nitrobenzaldehyde
p-anisaldehyde	**1e**	123-11-5	4-methoxybenzaldehyde
4-(methylthio)benzaldehyde	**1f**	3446-89-7	4-(methylthio)benzaldehyde
4-fluorobenzaldehyde	**1g**	459-57-4	4-fluorobenzaldehyde
4-chlorobenzaldehyde	**1h**	104-88-1	4-chlorobenzaldehyde
4-bromobenzaldehyde	**1i**	1122-91-4	4-bromobenzaldehyde
p-hydroxy benzaldehyde	**1j**	123-08-0	4-hydroxybenzaldehyde
vanillin	**1k**	121-33-5	4-hydroxy-3-methoxybenzaldehyde
4-(dimethylamino)benzaldehyde	**1l**	100-10-7	4-(dimethylamino)benzaldehyde
sinapinic dicarboxylic acid	**2a**	683214-28-0	2-[(4-hydroxy-3,5 dimethoxyphenyl) methylene]-propanedioic acid
sinapinic acid	**3a**	530-59-6	(E)-3-(4-hydroxy-3,5-dimethoxyphenyl) prop-2-enoic acid
cinnamic acid	**3b**	140-10-3	(2E)-3-phenylprop-2-enoic acid
4-methylcinnamic acid	**3c**	830-09-1	(E)-3-(4-methylphenyl)prop-2-enoic acid
4-nitrocinnamic acid	**3d**	619-89-6	(E)-3-(4-nitrophenyl)prop-2-enoic acid
4-methoxycinnamic acid	**3e**	830-09-1	(E)-3-(4-methoxyphenyl)prop-2-enoic acid
4-(methylthio)cinnamic acid	**3f**	102016-58-0	(E)-3-(4-methylthiophenyl)prop-2-enoic acid
4-fluorocinnamic acid	**3g**	459-32-5	(E)-3-(4-fluorophenyl)prop-2-enoic acid
4-chlorocinnamic acid	**3h**	1615-02-7	(E)-3-(4-chlorophenyl)prop-2-enoic acid
4-bromocinnamic acid	**3i**	1200-07-3	(E)-3-(4-bromophenyl)prop-2-enoic acid
p-coumaric acid	**3j**	501-98-4	(E)-3-(4-hydroxyphenyl)prop-2-enoic acid
ferulic acid	**3k**	1135-24-6	(E)-3-(4-hydroxy-3-methoxy-phenyl) prop-2-enoic acid
4-(dimethylamino)cinnamic acid	**3l**	1552-96-1	(E)-3-(4-dimethylaminophenyl) prop-2-enoic acid
4-vinylsyringol	**4a**	28343-22-8	2,6-dimethoxy-4-vinylphenol

General Information

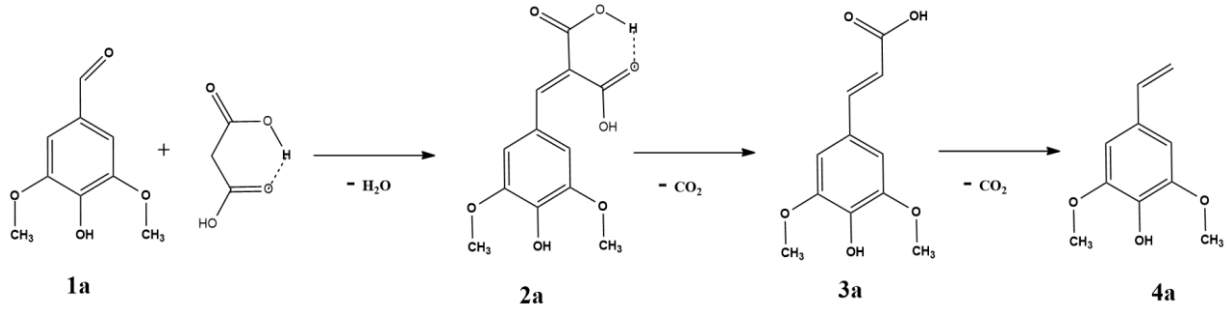


Figure S1: Reaction scheme of syringaldehyde with malonic acid

Materials

Syringaldehyde (**1a**), and all other chemicals (99% purity) were purchased from Sigma-Aldrich and were used as received. DMSO-d_6 was purchased from Cambridge Isotope with 99 atom% deuterated.

Methods

Instrumentation: ^{1}H-NMR spectroscopy measurements were performed on a Bruker Avance 400-MHz NMR system with DMSO-d_6 as solvent. Data was acquired using VnmrJ3 software. Chemical shifts are reported in ppm, relative to tetramethylsilane (TMS).

HPLC analysis was carried out using a Liquid Chromatographic system (Agilent 1100 series) equipped with a diode array detector (Agilent 1200 series) and an autosampler injector with a 20 µL loop (Agilent 1100 serie G1316A). The system was equipped with a Luna 5 µm C18 column (250 mm × 4.6 mm) using acetic acid:water:methanol (0.01:50:50, v/v/v) as the mobile phase. The flow rate was 1.0 mL/min at a temperature of 20 °C. Agilent´s ChemStation Software was used for data analysis. The quantitative determination of components in the reaction mixtures was carried out by the external standard method and was based on peak areas.

LC-MS analysis was performed using a Liquid Chromatographic system (Agilent 1200 series) equipped with a Luna 3 µm C18 column (250 x 2,0 mm) and a triple quadrupole (Agilent 6400 series).

Melting points were determined with a Büchi Melting Point B-540 apparatus.

Experimental Procedures and Spectral Data

Protocol for Knoevenagel-Doebner condensation in solution:
Malonic acid (1.0 g, 10 mmol) was dissolved in ethyl acetate (5.0 mL). Syringaldehyde (**1a**, 0.90 g, 5 mmol) and piperidine (0.20 mL, 2 mmol) were subsequently added. The reaction was heated to reflux and 50,0 µL samples were taken for reversed phase HPLC analysis. The samples were immediately diluted in 7.5 mL methanol, filtered and analysed using the method described under "Methods". The calculated percentage of peak area of the component of interest is in relation to the total area of peaks.

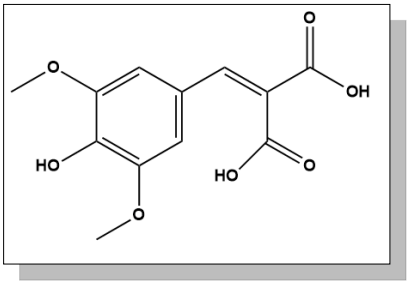
Protocol for optimized Knoevenagel condensation:
Malonic acid (1.0 g, 10 mmol) was dissolved in a minimum amount of ethyl acetate. Syringaldehyde (**1a**, 0.90 g, 5 mmol) and piperidine (0.20 mL, 2 mmol) were subsequently added. Then the solvent was removed by distillation under reduced pressure at 40°C. The solid was kept for 2 hours at 90°C for complete conversion. Samples were taken for reversed phase HPLC analysis and diluted in 7.5 mL methanol, filtered and analysed using the method described under "Methods". The calculated percentage of peak area of the component of interest is in relation to the total area of peaks.

In a total work-up procedure, the residue was dissolved in a small amount of a saturated aqueous $NaHCO_3$-solution and subsequently acidified to a pH of 2 by using 6 M HCl. The resulting precipitate was separated by filtration and washed with (demineralized) water. After recrystallization in a mixture of water-ethanol (4:1, v/v), the crystals were separated by filtration, suck dried using a suction pump and dried at 60°C in a vacuum oven.

4-Vinylsyringol, was purified with column chromatography with ethyl acetate as eluent. This resulted in a dark green-brown oil but after vacuum distillation and crystallization it resulted in a white solid.

Spectral Data

2-[(4-hydroxy-3,5 dimethoxyphenyl) methylene]-propanedioic acid (2a)



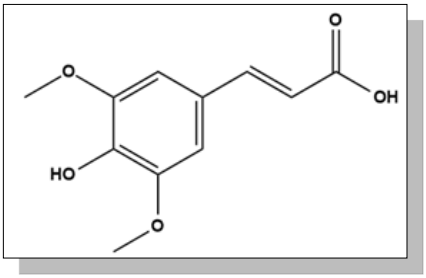
Light yellow solid, decomposes at 174°C

^{1}H NMR (400 MHz, DMSO) δ 13.09 (s, 2H), 9.10 (s, 1H), 7.43 (s, 1H), 6.95 (s, 2H), 3.74 (s, 6H)

^{13}C NMR (101 MHz, DMSO) δ 169.18, 166.08, 148.32, 139.99, 138.86, 125.46, 123.34, 108.04, 56.43

M calculated: 268.22 g/mol; MS (ESI) m/z observed $[M+H]^{+}$: 269 $[M-H]^{-}$: 267

3-(4-hydroxy-3,5-dimethoxyphenyl) prop-2-enoic acid (3a)



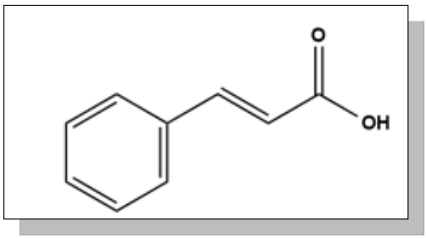
Light yellow solid, mp 198-199°C

^{1}H NMR (400 MHz, DMSO) δ 12.10 (s, 1H), 8.88 (s, 1H), 7.47 (d, J = 15.9 Hz, 1H), 6.97 (s, 2H), 6.40 (d, J = 15.9 Hz, 1H), 3.78 (s, 6H)

^{13}C NMR (101 MHz, DMSO) δ 168.50, 148.50, 145.32, 138.52, 125.11, 116.53, 106.48, 56.49

M calculated: 224.21 g/mol; MS (ESI) m/z observed $[M+H]^{+}$: 225 $[M-H]^{-}$: 223

(2E)-3-phenylprop-2-enoic acid (3b)



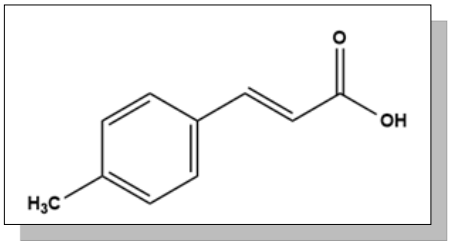
White solid, mp 133-134°C

^{1}H NMR (400 MHz, DMSO) δ 12.41 (s, 1H), 7.74 – 7.64 (m, 2H), 7.60 (d, J = 16.0 Hz, 1H), 7.47 – 7.37 (m, 3H), 6.54 (d, J = 16.0 Hz, 1H).

^{13}C NMR (101 MHz, DMSO) δ 168.07, 144.38, 134.71, 130.63, 129.33, 128.62, 119.70.

M calculated: 148.16 g/mol; MS (ESI) m/z observed $[M+H]^{+}$: 149 $[M-H]^{-}$: 147

(E)-3-(4-methylphenyl)prop-2-enoic acid (3c)



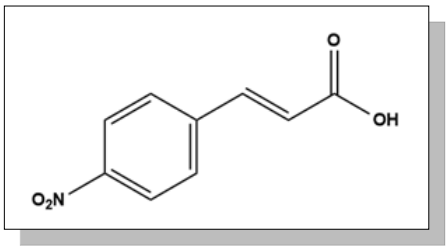
White solid, mp 196 - 198°C

^{1}H NMR (400 MHz, DMSO) δ 12.30 (s, 1H), 7.56 (dd, J = 12.0, 8.4 Hz, 3H), 7.23 (d, J = 8.0 Hz, 2H), 6.46 (d, J = 16.0 Hz, 1H), 2.33 (s, 3H).

^{13}C NMR (101 MHz, DMSO) δ 168.16, 144.36, 140.58, 131.97, 129.96, 128.63, 118.58, 21.44.

M calculated: 162.19 g/mol; MS (ESI) m/z observed $[M+H]^+$: 163 $[M-H]^-$: 161

(E)-3-(4-nitrophenyl)prop-2-enoic acid (3d)



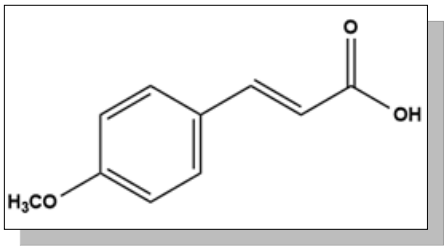
Yellow solid, decomposes at 274°C

^{1}H NMR (400 MHz, DMSO) δ 12.59 (s, 1H), 8.30 – 8.19 (m, 3H), 8.03 – 7.95 (m, 2H), 7.69 (dd, J = 13.4, 6.7 Hz, 2H), 6.76 (d, J = 16.1 Hz, 1H).

^{13}C NMR (101 MHz, DMSO) δ 167.58, 148.34, 141.56, 141.27, 129.69, 124.36.

M calculated: 193.16 g/mol; MS (ESI) m/z observed $[M+H]^+$: 194 $[M-H]^-$: 192

(E)-3-(4-methoxyphenyl)prop-2-enoic acid (3e)



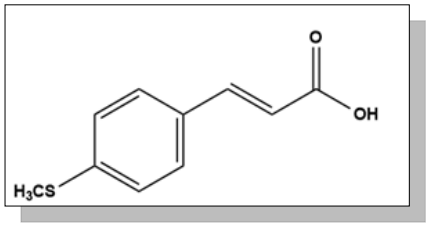
White solid, mp 170-172°C

^{1}H NMR (400 MHz, DMSO) δ 12.22 (s, 1H), 7.69 – 7.60 (m, 2H), 7.55 (d, J = 16.0 Hz, 1H), 7.01 – 6.94 (m, 2H), 6.38 (d, J = 16.0 Hz, 1H), 3.80 (s, 3H).

^{13}C NMR (101 MHz, DMSO) δ 168.29, 161.39, 144.17, 130.37, 127.29, 116.99, 114.80, 55.73.

M calculated: 178.18 g/mol; MS (ESI) m/z observed $[M+H]^+$: 179 $[M-H]^-$: 177

(E)-3-(4-methylthiophenyl)prop-2-enoic acid (3f)



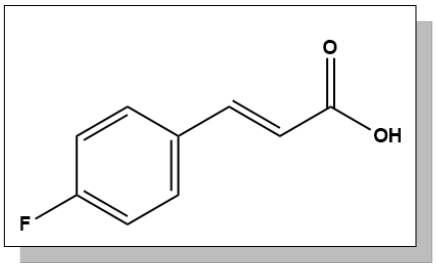
Light yellow solid, mp 174 - 175°C

^{1}H NMR (400 MHz, DMSO) δ 12.32 (s, 1H), 7.62 (d, J = 8.4 Hz, 2H), 7.55 (d, J = 16.0 Hz, 1H), 7.27 (d, J = 8.4 Hz, 2H), 6.48 (d, J = 16.0 Hz, 1H), 2.54 – 2.48 (m, 3H).

^{13}C NMR (101 MHz, DMSO) δ 168.14, 143.91, 141.79, 129.13, 126.07, 118.52, 14.66.

M calculated: 194.25 g/mol; MS (ESI) m/z observed $[M+H]^{+}$: 195 $[M-H]^{-}$: 193

(E)-3-(4-fluorophenyl)prop-2-enoic acid (3g)



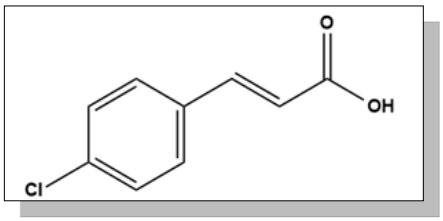
White solid, mp 207 - 209°C

^{1}H NMR (400 MHz, DMSO) δ 12.39 (s, 1H), 7.83 – 7.72 (m, 2H), 7.59 (d, J = 16.0 Hz, 1H), 7.30 – 7.18 (m, 2H), 6.50 (d, J = 16.0 Hz, 1H).

^{13}C NMR (101 MHz, DMSO) δ 168.01, 164.84, 162.37, 143.14, 131.35 (d, J = 3.1 Hz), 130.92 (d, J = 8.6 Hz), 119.58 (d, J = 2.3 Hz), 116.31 (d, J = 21.7 Hz).

M calculated: 166.15 g/mol; MS (ESI) m/z observed $[M+H]^{+}$: 167 $[M-H]^{-}$: 165

(E)-3-(4-chlorophenyl)prop-2-enoic acid (3h)



White solid, mp 236 - 238°C

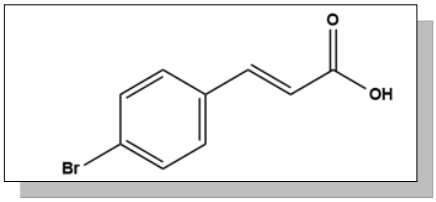
^{1}H NMR (400 MHz, DMSO) δ 12.42 (s, 1H), 7.73 (d, J = 8.5 Hz, 2H), 7.62 – 7.53 (m, 1H), 7.47 (d, J = 8.5 Hz, 2H), 6.56 (d, J = 16.0 Hz, 1H).

^{13}C NMR (101 MHz, DMSO) δ 167.86, 142.89, 135.15, 133.67, 130.34, 129.36, 120.59.

M calculated: 181.9 and 183.9 g/mol;

MS (ESI) m/z observed $[M-Cl^{\bullet}]^{+}$ m/z 148 $[M-Cl]^{-}$: 183 and 185

(E)-3-(4-bromophenyl)prop-2-enoic acid (3i)



Light yellow solid, mp 248 - 251°C

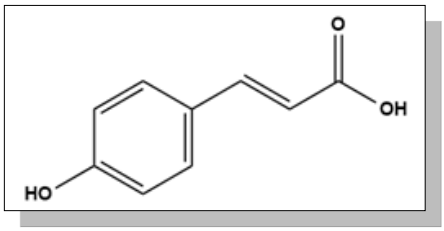
^{1}H NMR (400 MHz, DMSO) δ 10.87 (s, 1H), 7.59 – 7.55 (m, 2H), 7.55 – 7.51 (m, 2H), 7.51 – 7.45 (m, 1H), 6.50 (d, J = 16.0 Hz, 1H).

^{13}C NMR (101 MHz, DMSO) δ 167.85, 143.00, 133.98, 132.29, 130.55, 123.97, 120.62.

M calculated: 226.1 and 228.1 g/mol;

MS (ESI) m/z observed $[M\text{-}Br^{\bullet}]^{+}$ m/z 148 $[M\text{-}Br]^{-}$: 225 and 227

(E)-3-(4-hydroxyphenyl)prop-2-enoic acid (3j)



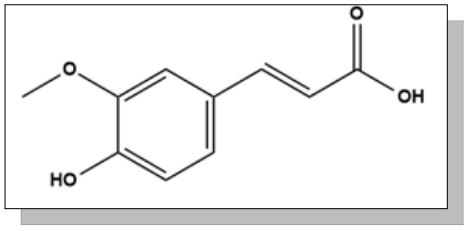
White solid, mp 212 - 214°C

^{1}H NMR (400 MHz, DMSO) δ 12.11 (s, 1H), 10.02 (s, 1H), 7.59 – 7.47 (m, 3H), 6.82 (d, J = 8.5 Hz, 2H), 6.32 (d, J = 16.0 Hz, 1H).

^{13}C NMR (101 MHz, DMSO) δ 168.47, 160.06, 144.66, 130.53, 125.75, 116.23, 115.80.

M calculated: 164.16 g/mol; MS (ESI) m/z observed $[M+H]^{+}$: 165 $[M-H]^{-}$: 163

(E)-3-(4-hydroxy-3-methoxy-phenyl)prop-2-enoic acid (3k)



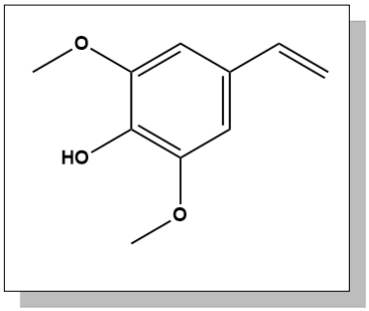
Light yellow solid, mp 171 - 173°C

^{1}H NMR (400 MHz, DMSO) δ 12.12 (s, 1H), 9.54 (s, 1H), 7.49 (d, J = 15.9 Hz, 1H), 7.28 (d, J = 1.9 Hz, 1H), 7.08 (dd, J = 8.2, 1.9 Hz, 1H), 6.83 – 6.76 (m, 1H), 6.36 (d, J = 15.9 Hz, 1H), 3.82 (s, 3H).

^{13}C NMR (101 MHz, DMSO) δ 168.49, 149.54, 148.37, 144.99, 126.25, 123.28, 116.05, 111.59, 56.12.

M calculated: 194.18 g/mol; MS (ESI) m/z observed $[M+H]^{+}$: 195 $[M-H]^{-}$: 193

2,6-dimethoxy-4-vinylphenol (4a)



White solid, mp 53 - 54°C

^{1}H NMR (400 MHz, DMSO) δ 8.44 (s, 1H), 6.73 (s, 1H), 6.66 – 6.53 (m, 1H), 5.67 (dd, J = 17.6, 0.9 Hz, 1H), 5.09 (dd, J = 10.9, 0.8 Hz, 1H), 3.77 (s, 6H).

^{13}C NMR (101 MHz, DMSO) δ 148.51, 137.45, 136.29, 128.21, 111.78, 104.24, 56.40.

M calculated: 180.20 g/mol; MS (ESI) m/z observed $[M+H]^{+}$: 181 $[M-H]^{-}$: 179

HPLC area as function of time

HPLC area % Syringaldehyde

Time (min)	40°C	50°C	60°C	70°C	80°C	90°C	100°C	110°C	120°C	130°C
0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
20	98,3	98,1	99,1	98,8	53,4	45,0	37,7	25,4	7,1	0,0
40	97,8	94,6	94,1	90,6	43,1	27,3	12,4	2,7	0,0	0,0
60	96,8	93,3	90,8	83,9	33,5	12,4	3,6	0,0	0,0	0,0
80	96,5	92,1	86,9	70,7	25,7	4,9	0,0	0,0	0,0	0,0
100	96,2	90,7	82,6	63,5	17,9	0,0	0,0	0,0	0,0	0,0
120	95,2	87,8	72,3	53,6	11,4	0,0	0,0	0,0	0,0	0,0
140	95,1	86,8	68,0	49,1	8,3	0,0	0,0	0,0	0,0	0,0
160	94,5	85,8	64,3	42,3	3,8	0,0	0,0	0,0	0,0	0,0
180	95,1	85,2	61,7	35,3	0,0	0,0	0,0	0,0	0,0	0,0
200	93,9	82,9	56,5	29,1	0,0	0,0	0,0	0,0	0,0	0,0

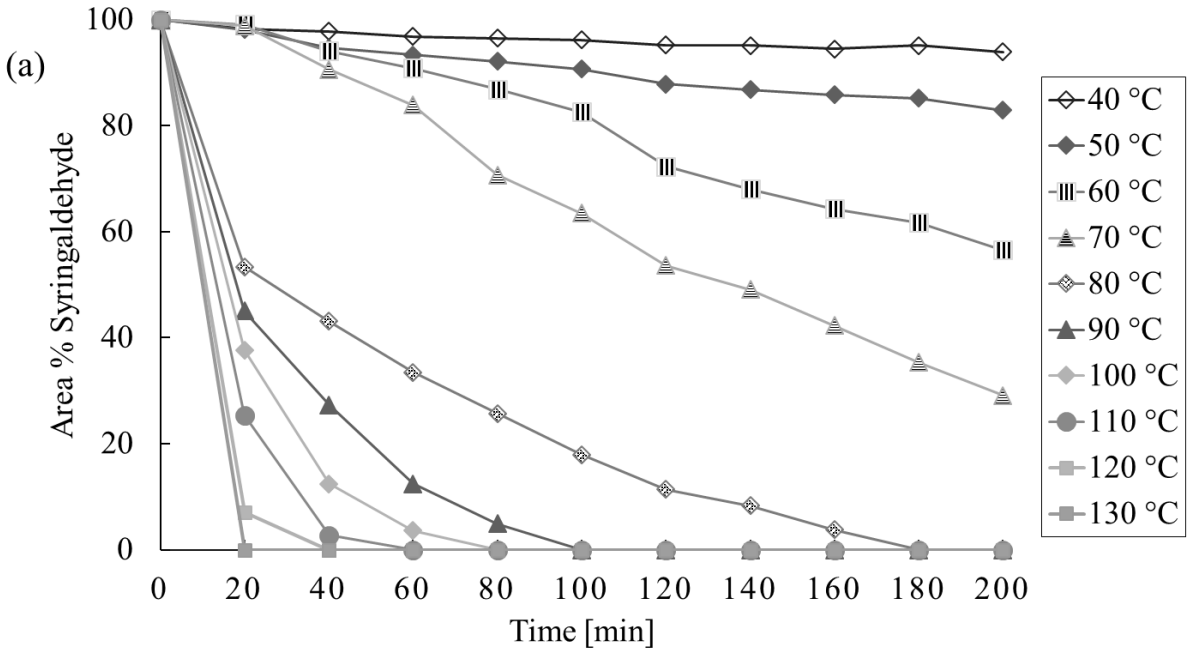


Figure S1. HPLC area % at 300 nm of syringaldehyde (**1a**) as a function of time at various reaction temperatures.

Reagents and conditions: syringaldehyde, 2 eq. malonic acid and 0.4 eq piperidine in ethyl acetate; concentrated in vacuo at 40°C; resulting solvent-free mixture was heated at specified temperature.

HPLC area % Sinapinic dicarboxylic acid

Time (min)	40°C	50°C	60°C	70°C	80°C	90°C	100°C	110°C	120°C	130°C
0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
20	1,5	1,7	0,7	1,1	11,2	10,0	7,1	3,8	0,6	0,0
40	2,0	5,2	5,6	9,2	9,8	5,3	2,1	0,0	0,0	0,0
60	3,0	6,5	9,0	14,1	8,3	2,4	0,0	0,0	0,0	0,0
80	3,3	7,7	12,1	12,8	6,5	1,2	0,0	0,0	0,0	0,0
100	3,7	9,1	14,8	12,3	4,8	0,0	0,0	0,0	0,0	0,0
120	4,6	9,4	13,3	11,4	3,1	0,0	0,0	0,0	0,0	0,0
140	4,7	9,7	13,6	10,6	2,5	0,0	0,0	0,0	0,0	0,0
160	5,3	10,2	13,6	9,8	1,7	0,0	0,0	0,0	0,0	0,0
180	4,7	13,3	17,7	8,5	0,8	0,0	0,0	0,0	0,0	0,0
200	6,0	11,3	13,0	7,5	0,2	0,0	0,0	0,0	0,0	0,0

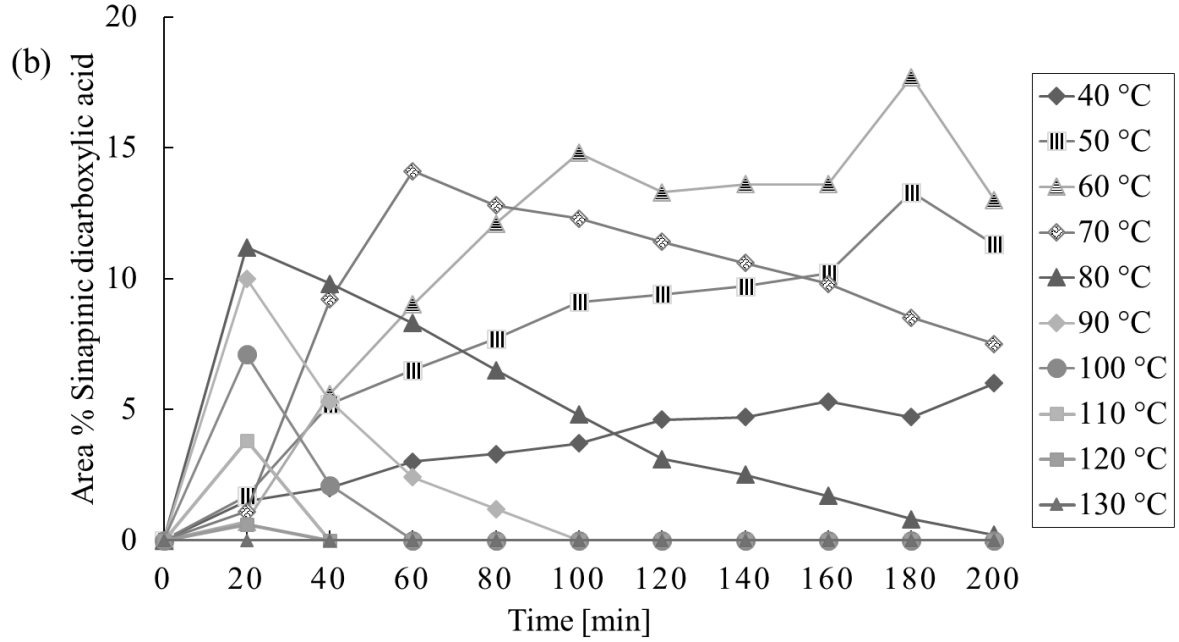


Figure S2. HPLC area % at 300 nm of sinapinic dicarboxylic acid (**2a**) as a function of time at various reaction temperatures.

Reagents and conditions: syringaldehyde, 2 eq. malonic acid and 0.4 eq piperidine in ethyl acetate; concentrated in vacuo at 40°C; resulting solvent-free mixture was heated at specified temperature.

HPLC area % Sinapinic acid

Time (min)	40°C	50°C	60°C	70°C	80°C	90°C	100°C	110°C	120°C	130°C
0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
20	0,0	0,0	0,0	0,0	35,2	44,7	54,6	69,6	87,8	66,3
40	0,0	0,0	0,0	6,0	47,0	67,0	84,5	93,9	13,0	9,1
60	0,0	0,0	0,0	1,8	58,0	84,7	95,3	88,3	0,0	0,0
80	0,0	0,0	0,9	16,4	67,5	93,2	98,4	27,0	0,0	0,0
100	0,0	0,0	2,3	24,1	77,0	99,3	97,6	0,0	0,0	0,0
120	0,0	2,7	16,3	34,8	85,1	99,0	96,1	0,0	0,0	0,0
140	0,0	3,3	18,3	40,1	88,7	99,1	93,1	0,0	0,0	0,0
160	0,0	3,8	21,9	47,6	94,1	98,9	87,8	0,0	0,0	0,0
180	0,0	1,4	20,3	56,0	98,3	97,6	75,2	0,0	0,0	0,0
200	0,0	5,7	30,2	63,2	99,0	96,1	64,2	0,0	0,0	0,0

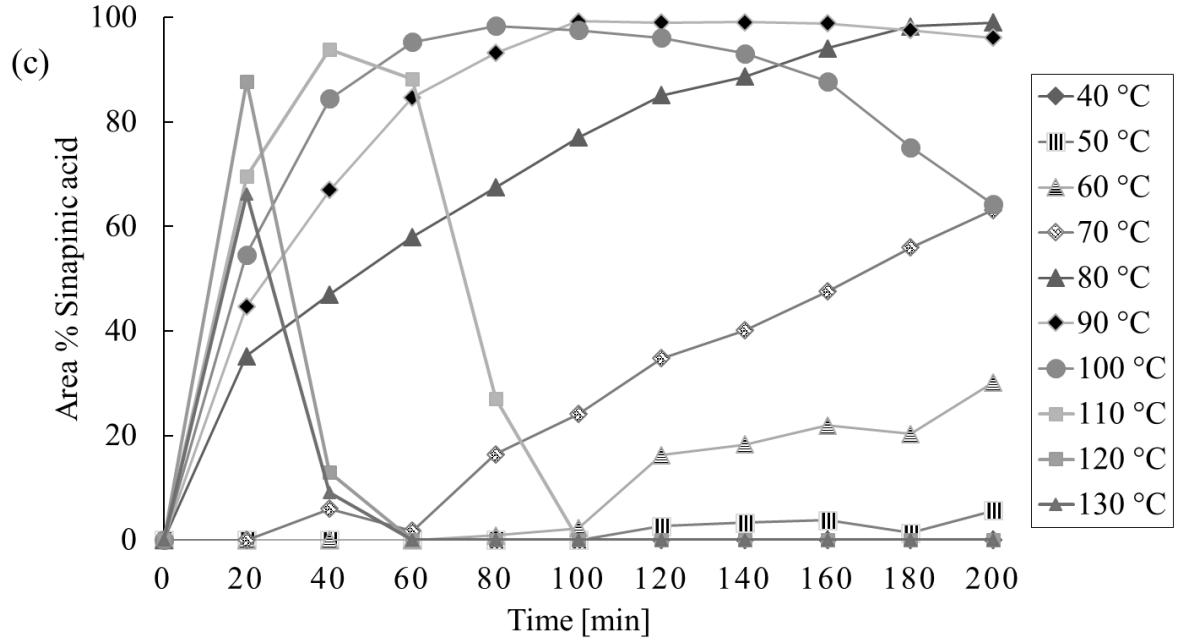


Figure S3. HPLC area % at 300 nm of sinapinic acid (**3a**) as a function of time at various reaction temperatures.

Reagents and conditions: syringaldehyde, 2 eq. malonic acid and 0.4 eq piperidine in ethyl acetate; concentrated in vacuo at 40°C; resulting solvent-free mixture was heated at specified temperature.

HPLC area % 4-vinylsyringol

Time (min)	40°C	50°C	60°C	70°C	80°C	90°C	100°C	110°C	120°C	130°C
0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
20	0,0	0,0	0,0	0,0	0,1	0,2	0,4	0,8	2,4	28,8
40	0,0	0,0	0,0	0,0	0,2	0,3	0,5	2,7	69,9	40,8
60	0,0	0,0	0,0	0,0	0,2	0,3	0,7	9,9	36,0	26,9
80	0,0	0,0	0,0	0,0	0,2	0,4	1,2	62,0	26,7	17,4
100	0,0	0,0	0,0	0,1	0,2	0,4	2,0	67,6	19,3	14,0
120	0,0	0,0	0,0	0,1	0,2	0,6	3,4	52,3	16,1	11,7
140	0,0	0,0	0,0	0,1	0,2	0,7	5,9	41,9	13,8	8,3
160	0,0	0,0	0,0	0,1	0,2	0,7	10,5	33,9	10,9	6,8
180	0,0	0,0	0,0	0,1	0,3	0,9	22,4	23,8	7,9	4,2
200	0,0	0,0	0,1	0,1	0,3	1,1	30,7	13,5	5,8	1,8

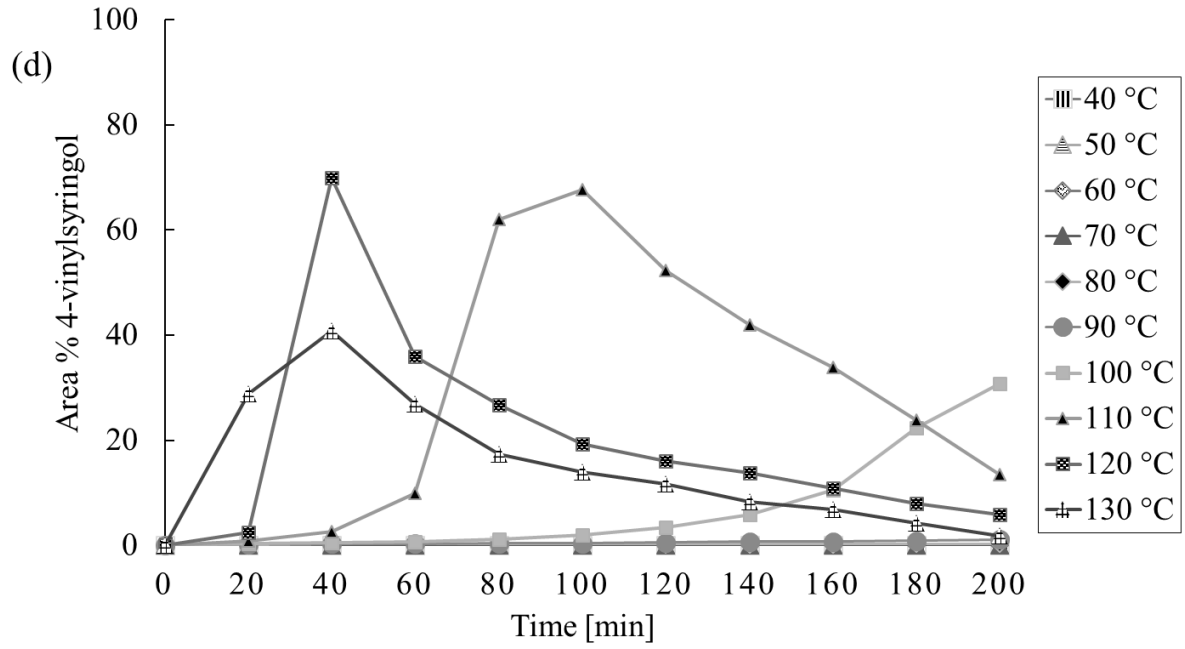


Figure S4. HPLC area % at 300 nm of 4-vinylsyringol (**4a**) as a function of time at various reaction temperatures.

Reagents and conditions: syringaldehyde, 2 eq. malonic acid and 0.4 eq piperidine in ethyl acetate; concentrated in vacuo at 40°C; resulting solvent-free mixture was heated at specified temperature.

NMR and MS spectra

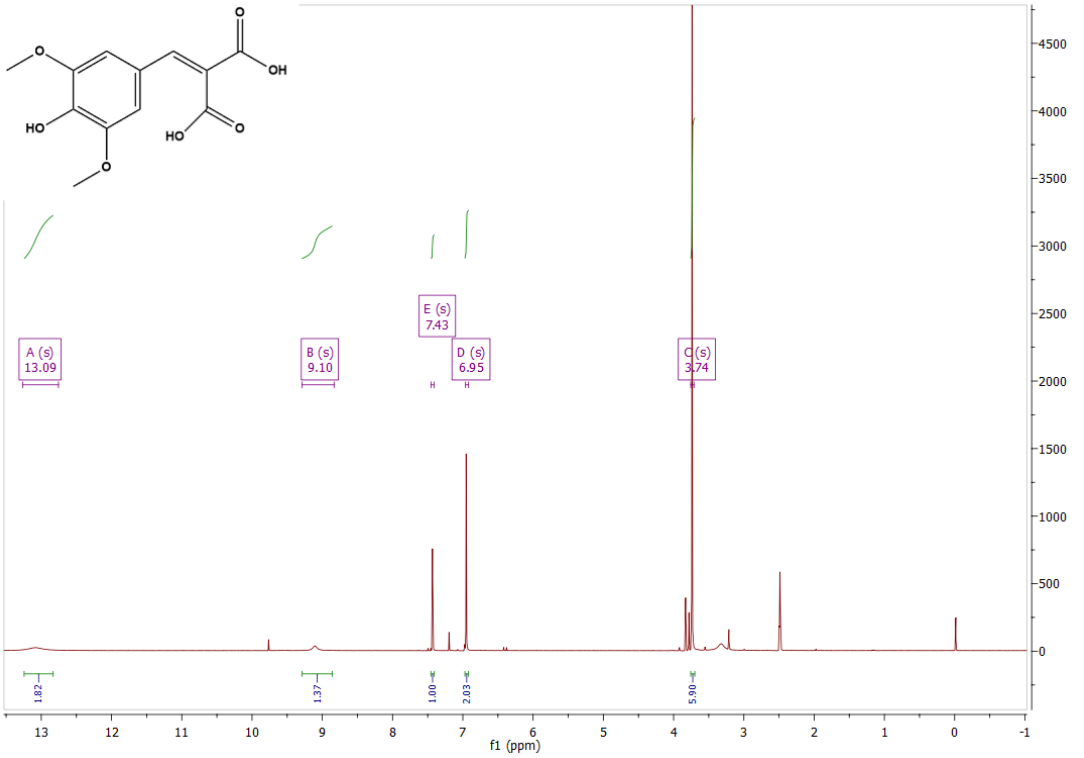


Figure S5. ^{1}H NMR spectrum of sinapinic dicarboxylic acid **2a**

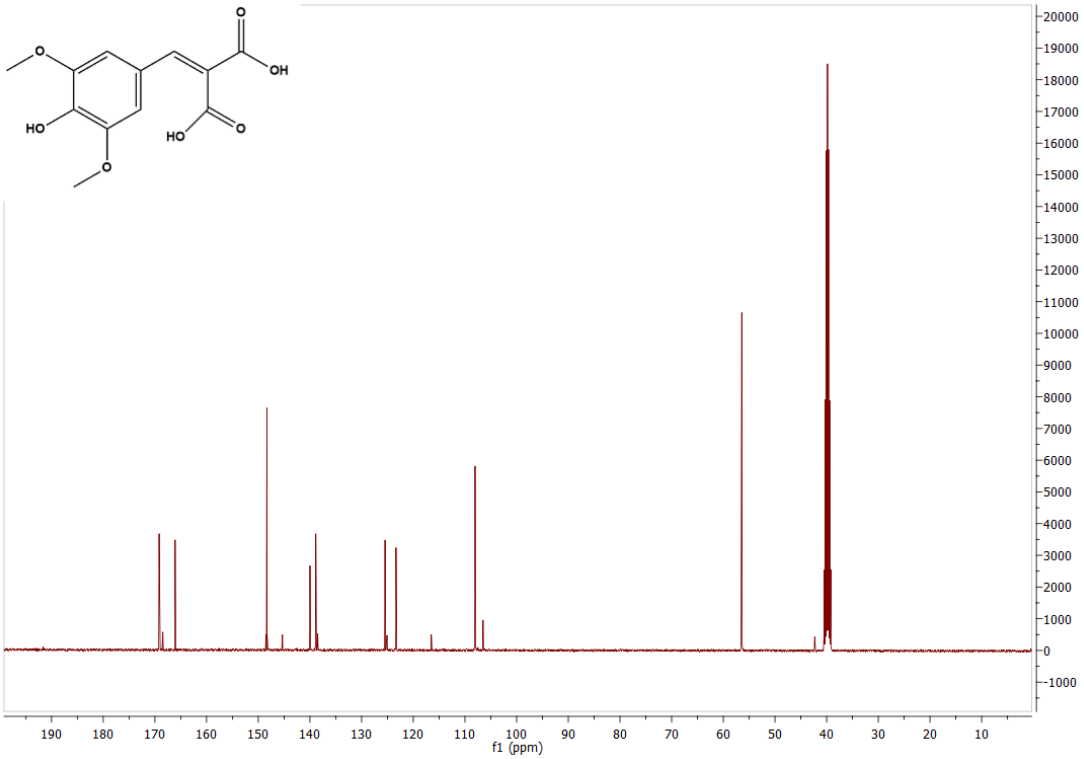


Figure S6. ^{13}C NMR spectrum of sinapinic dicarboxylic acid **2a**

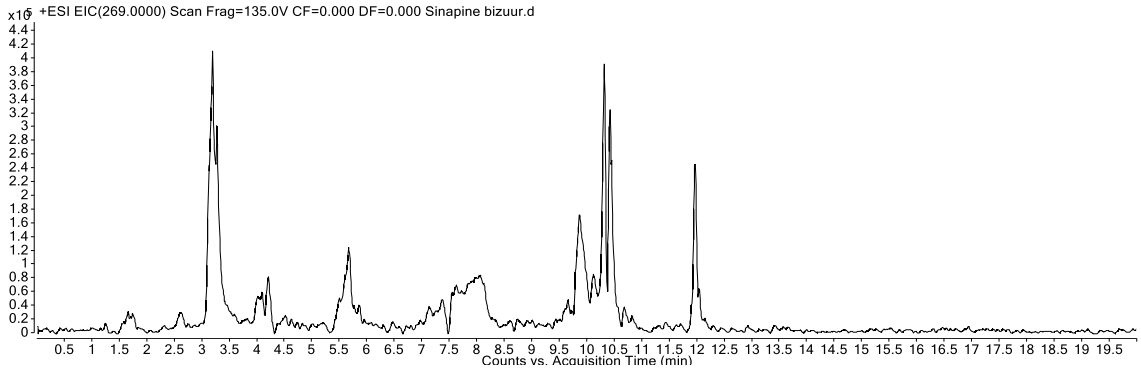


Figure S7. Extracted-ion chromatogram of sinapinic dicarboxylic acid (M= 268 g/mol) in positive ion mode identified by $[M+H]^+$ m/z 269

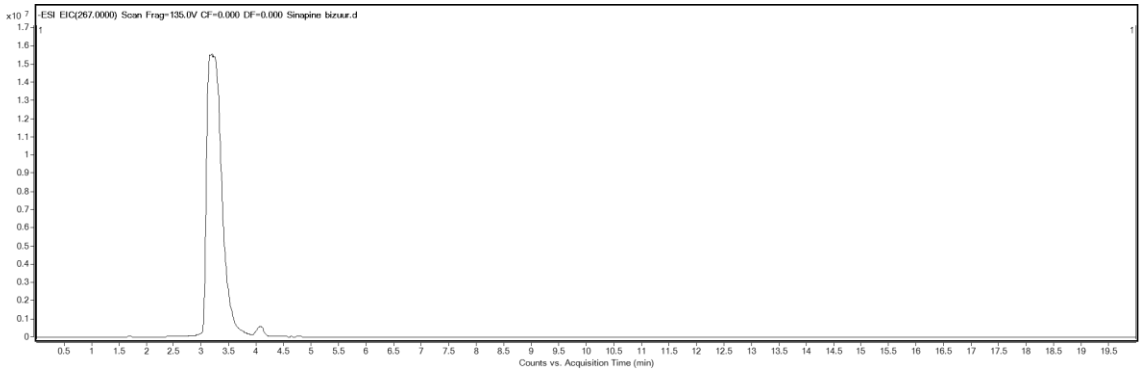


Figure S8. Extracted-ion chromatogram of sinapinic dicarboxylic acid (M= 268 g/mol) in negative ion mode identified by $[M–H]^-$ m/z 267

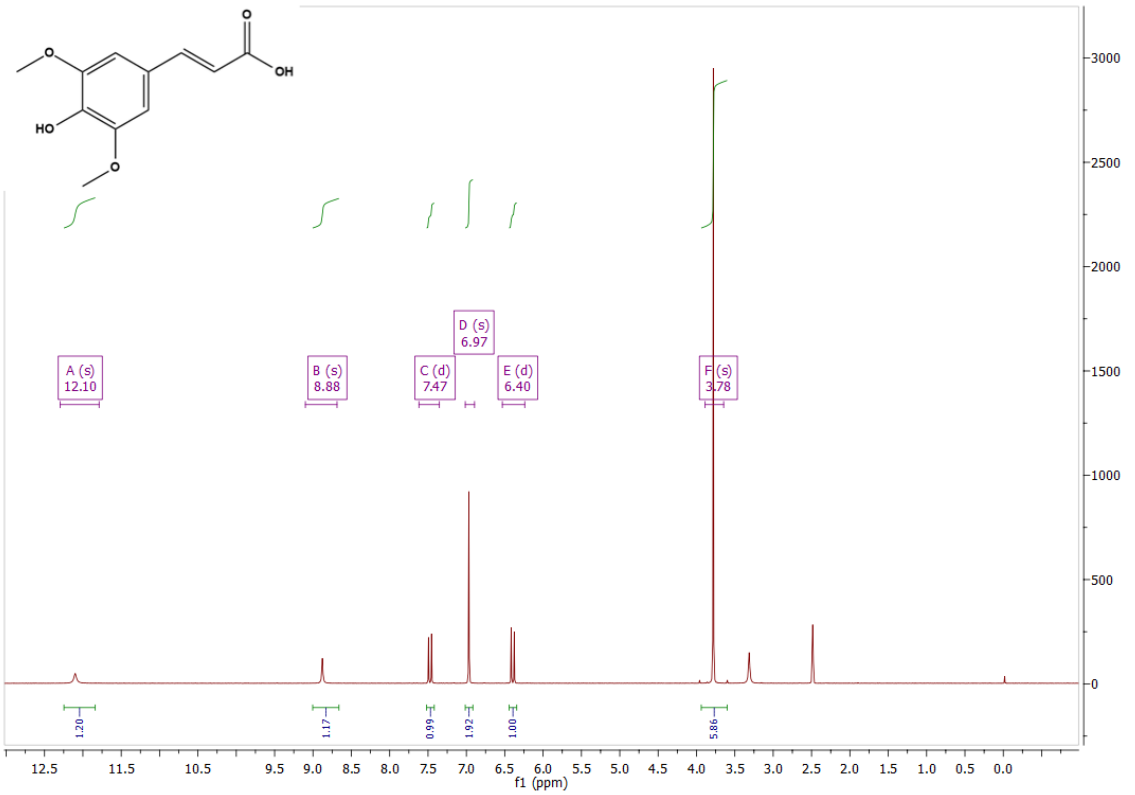


Figure S9. ^{1}H NMR spectrum of sinapinic acid **3a**

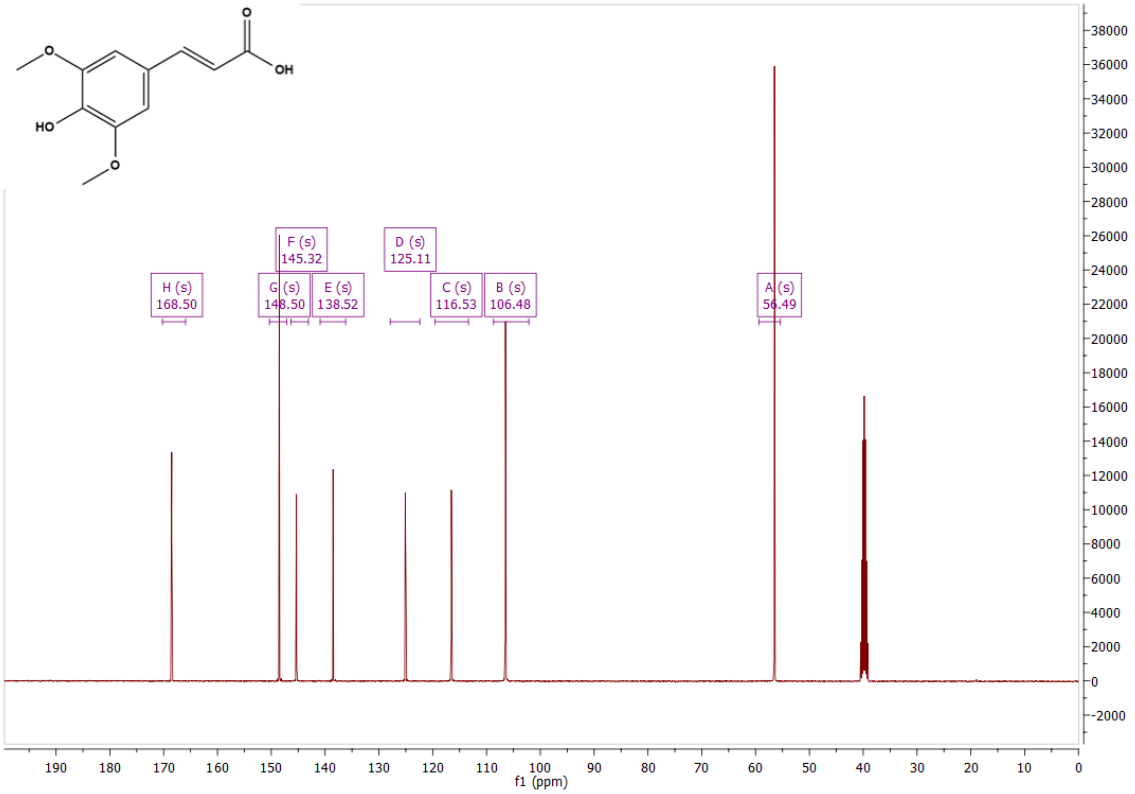


Figure S10. ^{13}C NMR spectrum of sinapinic acid **3a**

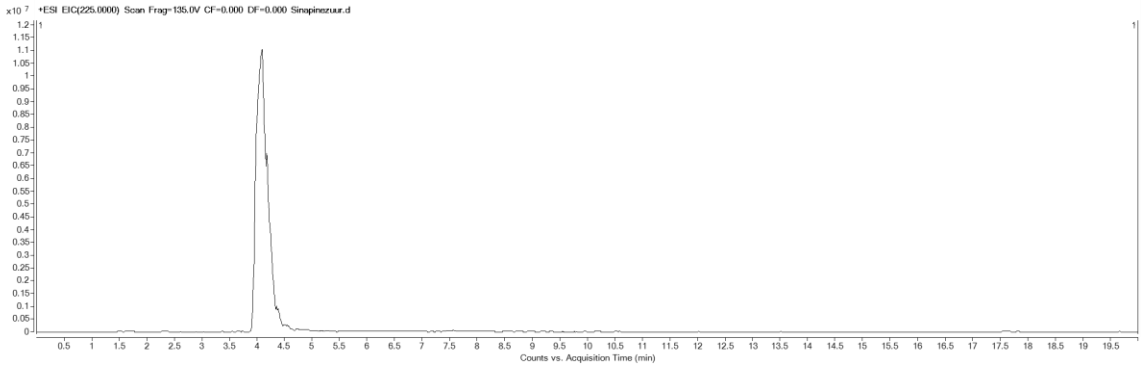


Figure S11. Extracted-ion chromatogram of sinapinic acid (M= 224 g/mol) in positive ion mode identified by $[M+H]^+$ m/z 225

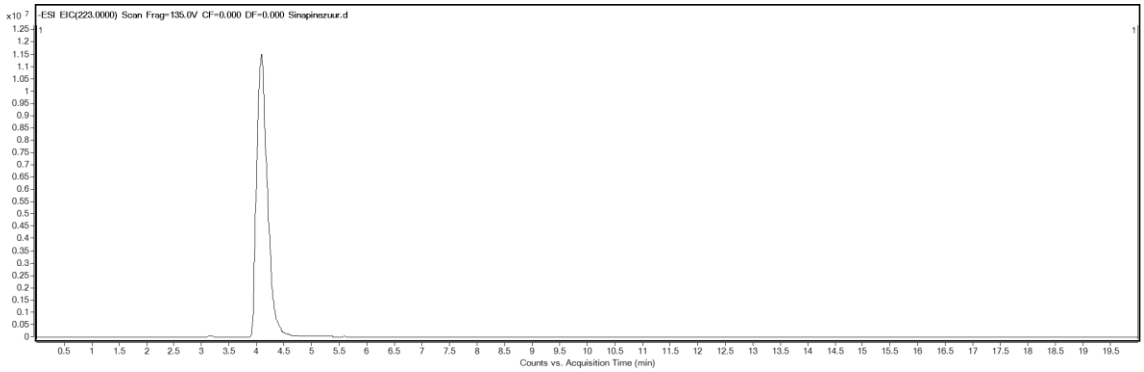


Figure S12. Extracted-ion chromatogram of sinapinic acid (M= 224 g/mol) in negative ion mode identified by $[M–H]^-$ m/z 223

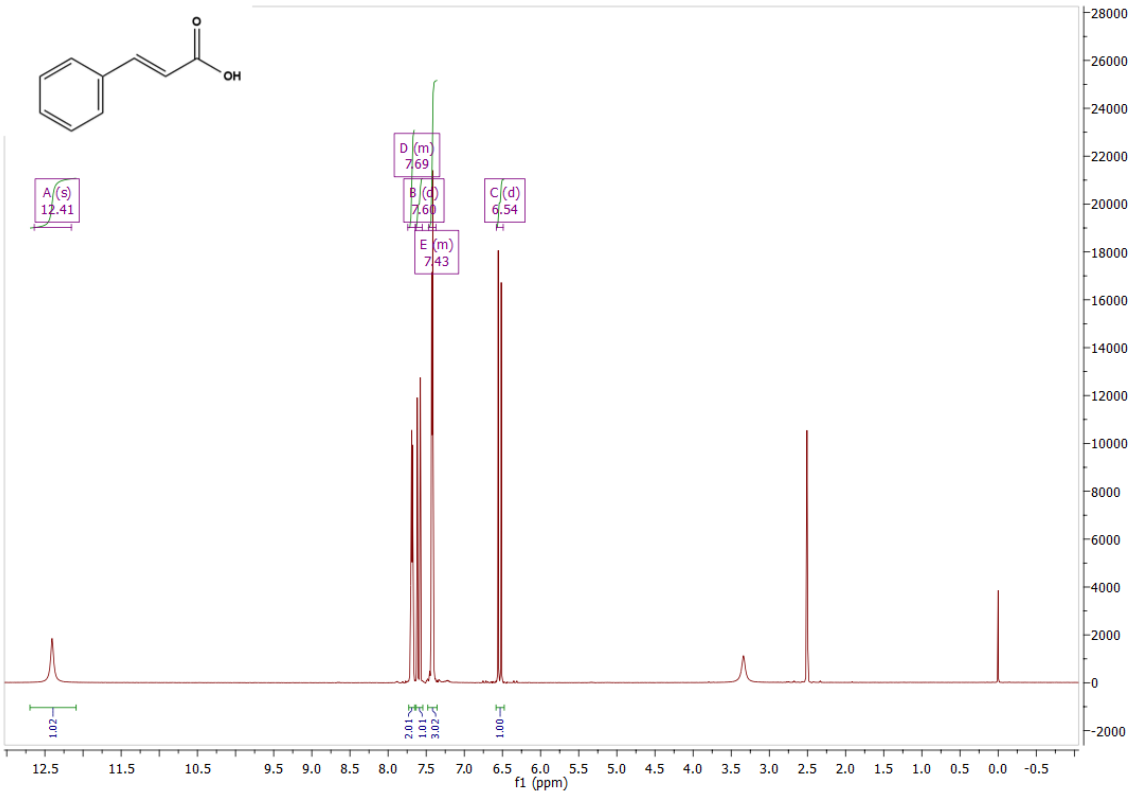


Figure S13. ^{1}H NMR spectrum of cinnamic acid **3b**

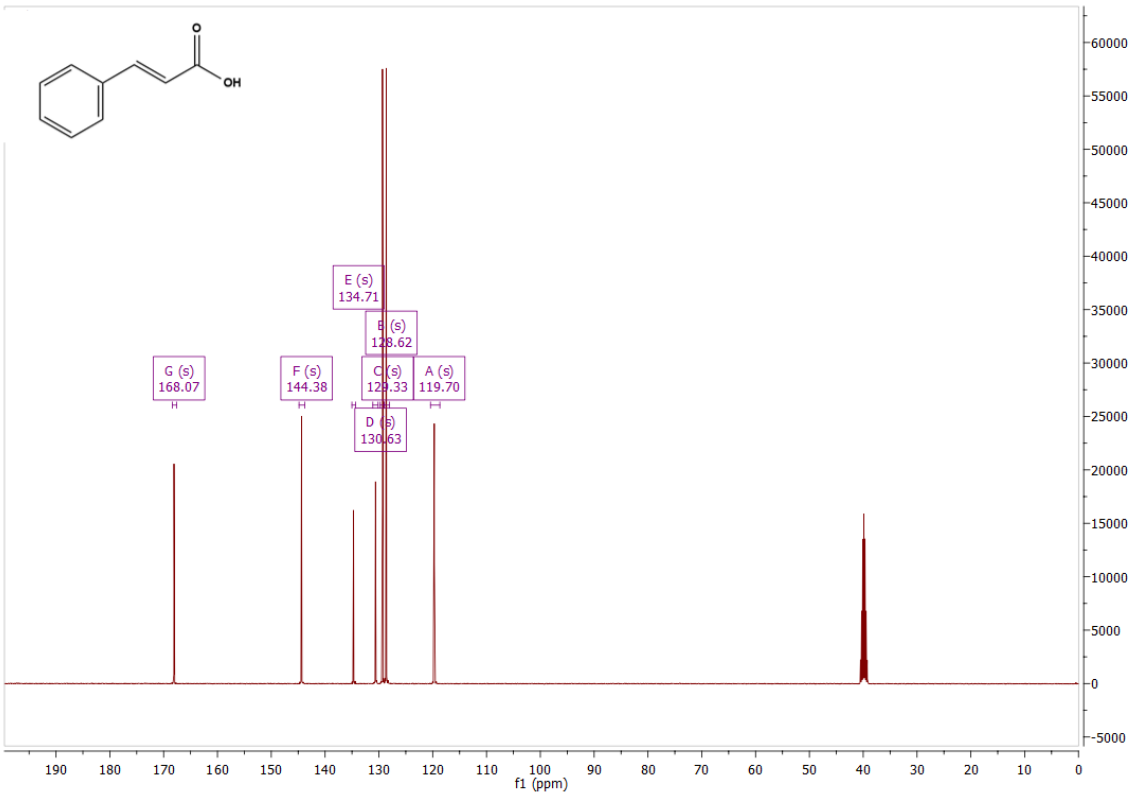


Figure S14. ^{13}C NMR spectrum of cinnamic acid **3b**

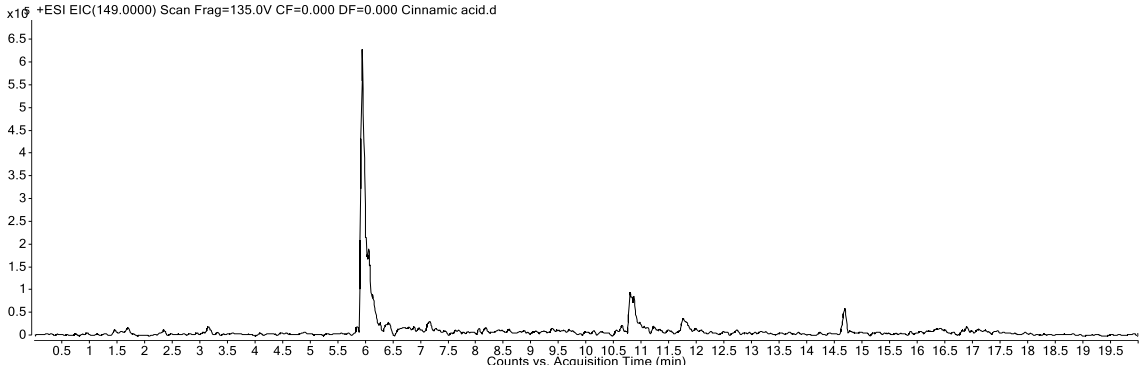


Figure S15. Extracted-ion chromatogram of cinnamic acid (M= 148 g/mol) in positive ion mode identified by $[M+H]^+$ m/z 149

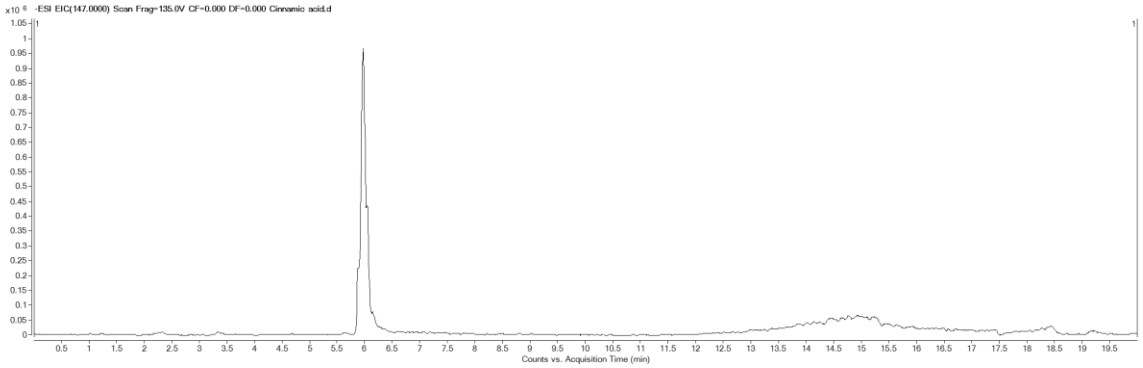


Figure S16. Extracted-ion chromatogram of cinnamic acid (M= 148 g/mol) in negative ion mode identified by $[M–H]^-$ m/z 147

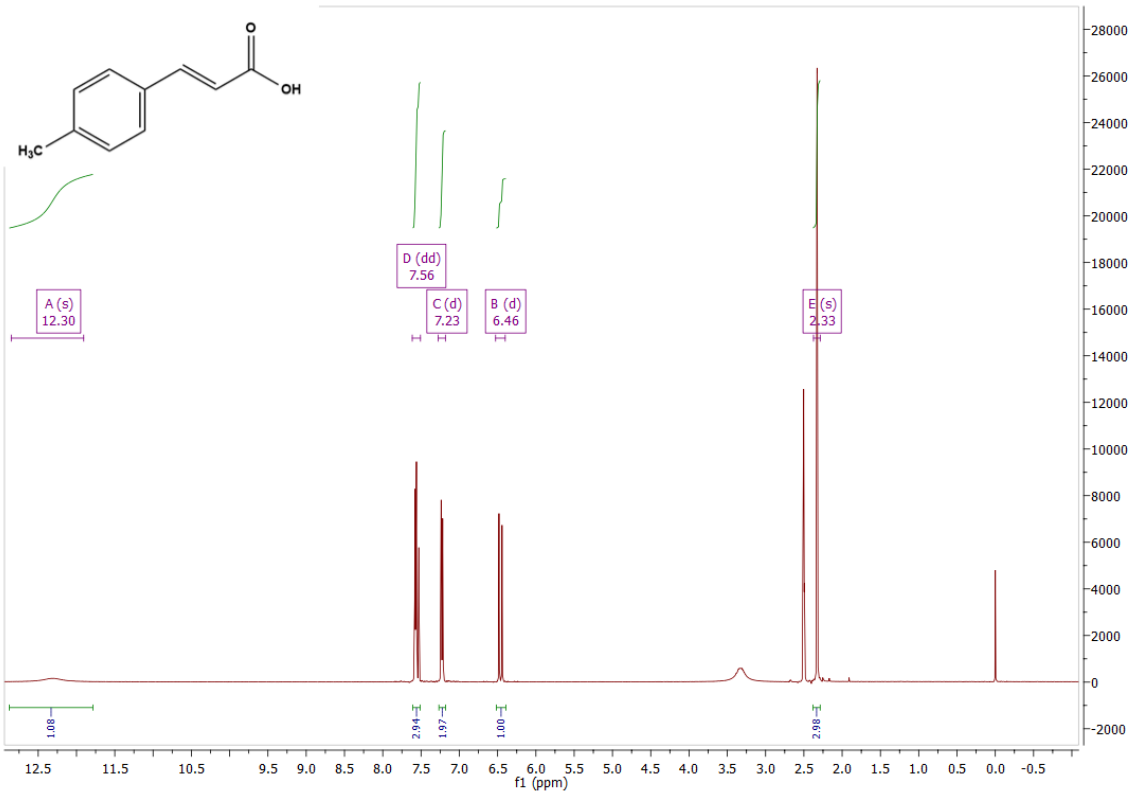


Figure S17. ^{1}H NMR spectrum of 4-methylcinnamic acid **3c**

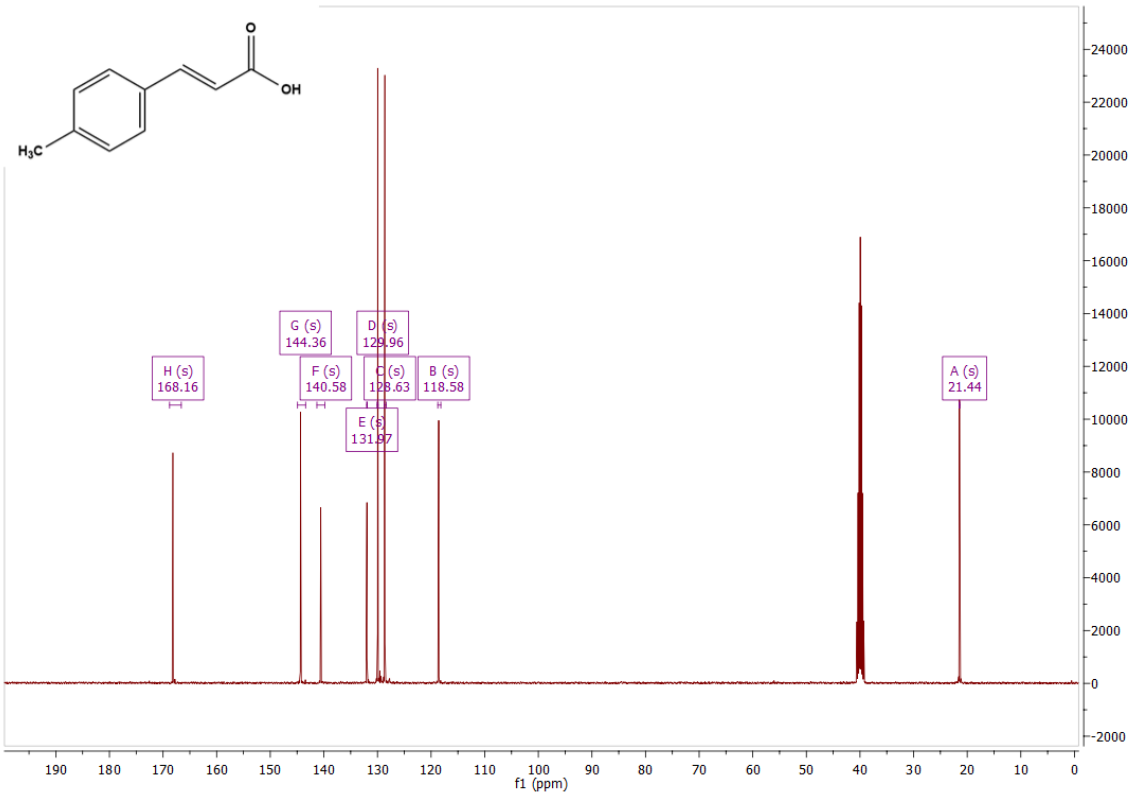


Figure S18. ^{13}C NMR spectrum of 4-methylcinnamic acid **3c**

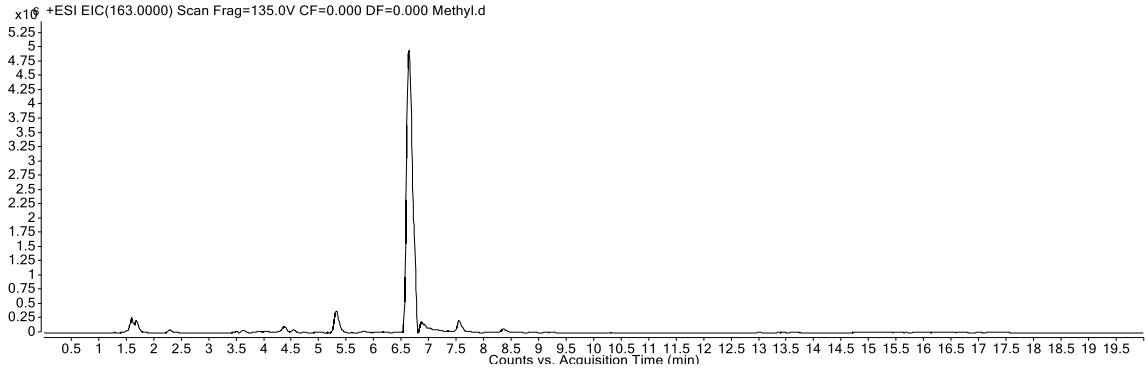


Figure S19. Extracted-ion chromatogram of 4-methylcinnamic acid (M= 162 g/mol) in positive ion mode identified by $[M+H]^+$ m/z 163

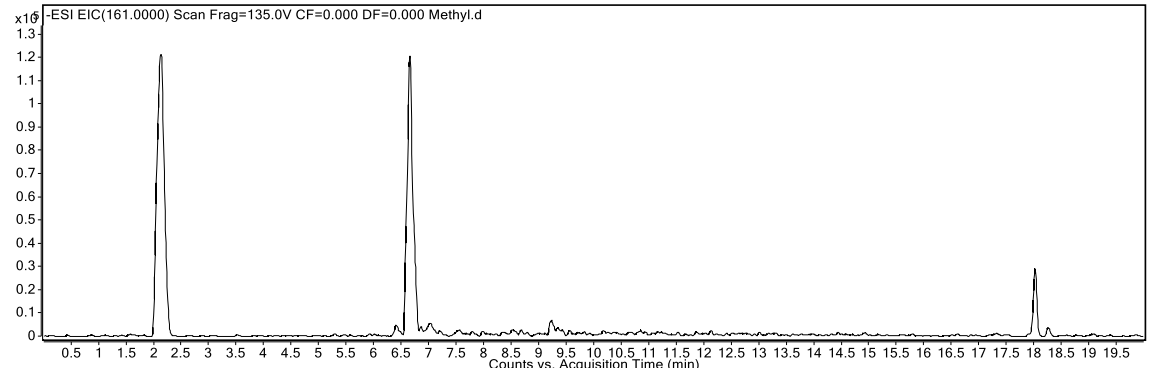


Figure S20. Extracted-ion chromatogram of 4-methylcinnamic acid (M= 162 g/mol) in negative ion mode identified by $[M–H]^-$ m/z 161

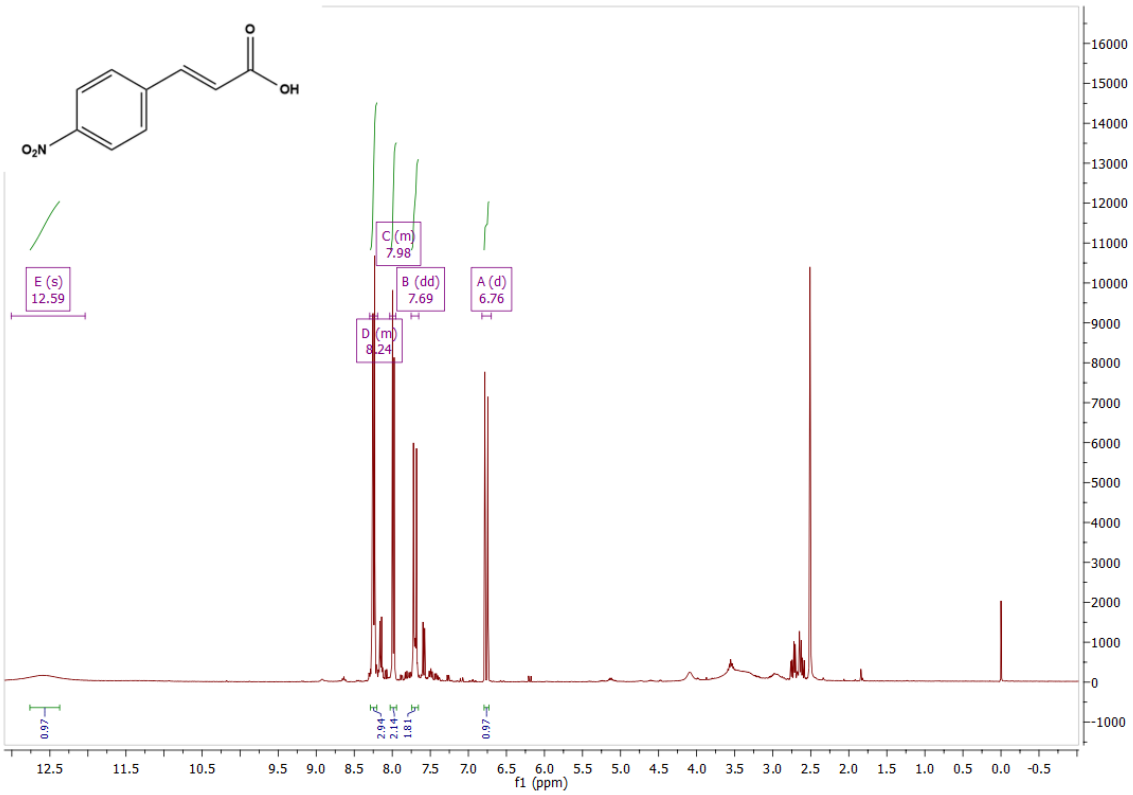


Figure S21. ^{1}H NMR spectrum of 4-nitrocinnamic acid **3d**

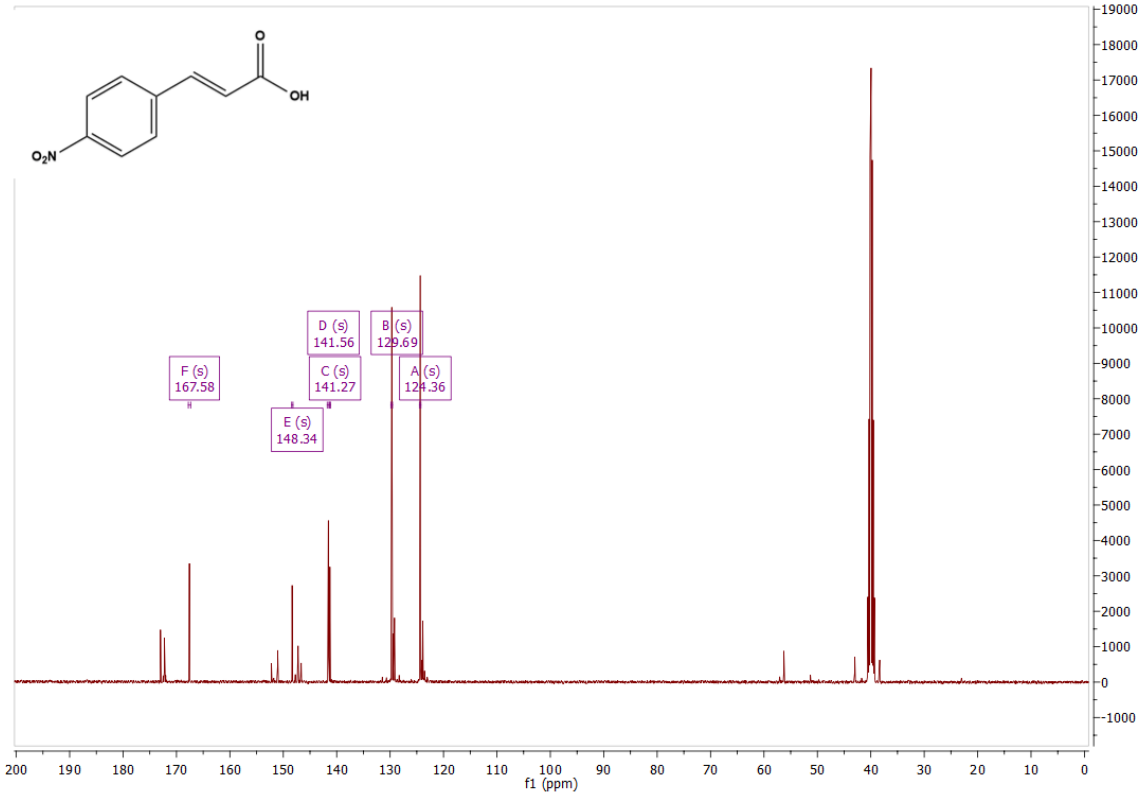


Figure S22. ^{13}C NMR spectrum of 4-nitrocinnamic acid **3d**

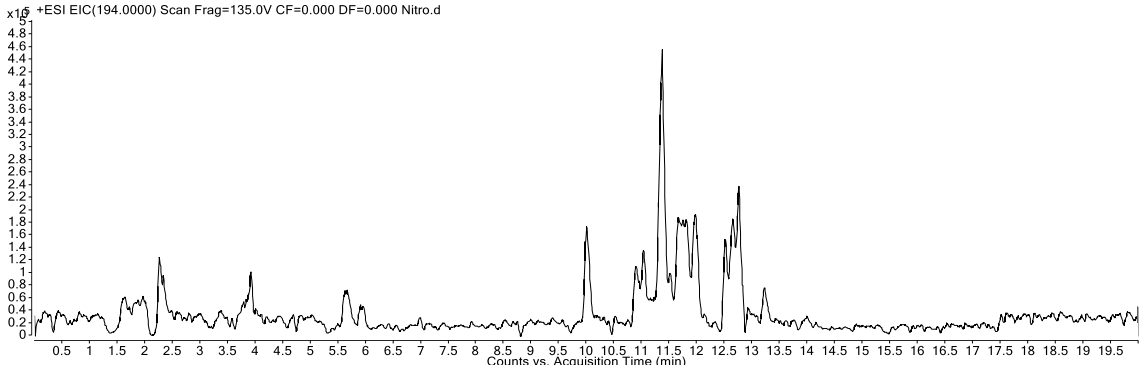


Figure S23. Extracted-ion chromatogram of 4-nitrocinnamic acid (M= 193 g/mol) in positive ion mode identified by $[M+H]^+$ m/z 194

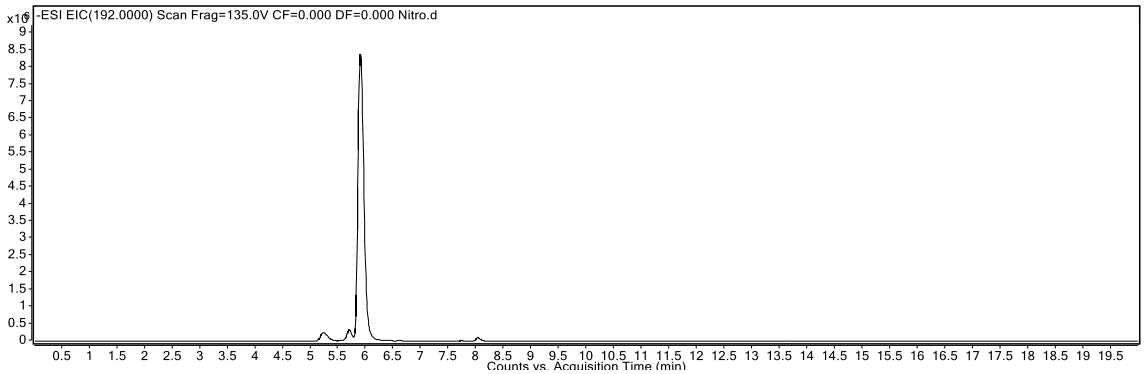


Figure S24. Extracted-ion chromatogram of 4-nitrocinnamic acid (M= 193 g/mol) in negative ion mode identified by $[M–H]^-$ m/z 192

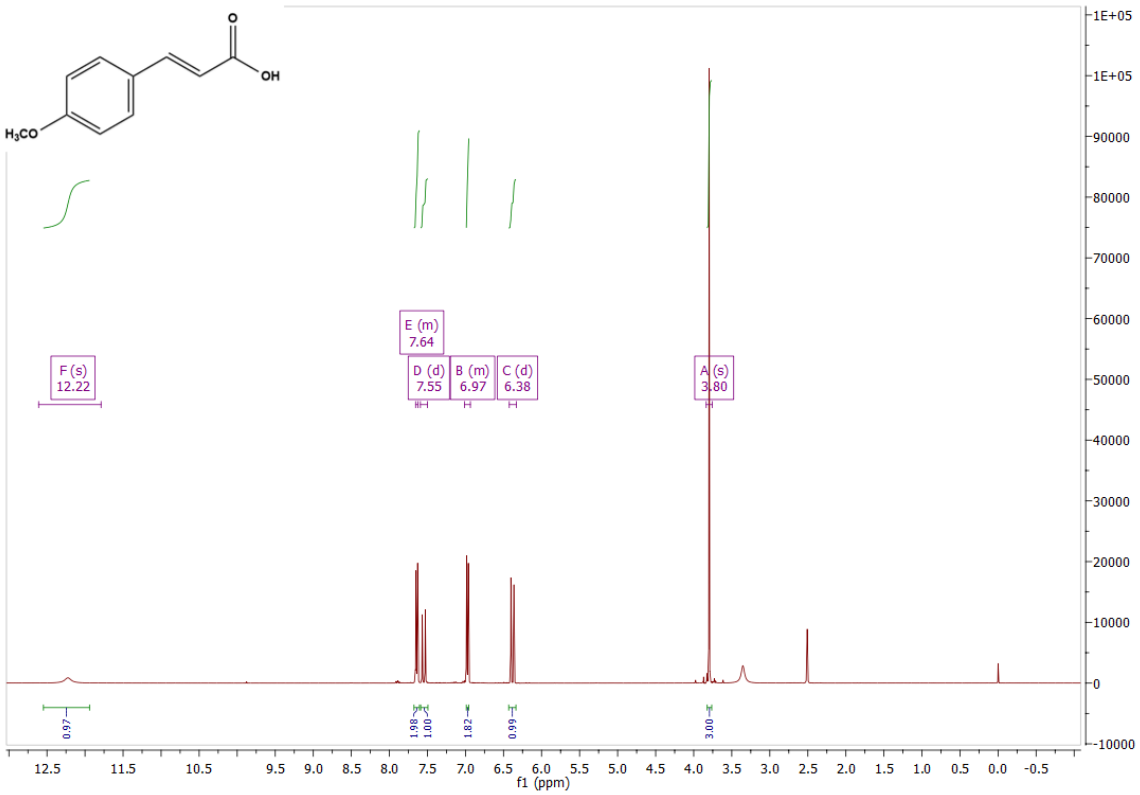


Figure S25. ^{1}H NMR spectrum of 4-methoxycinnamic acid **3e**

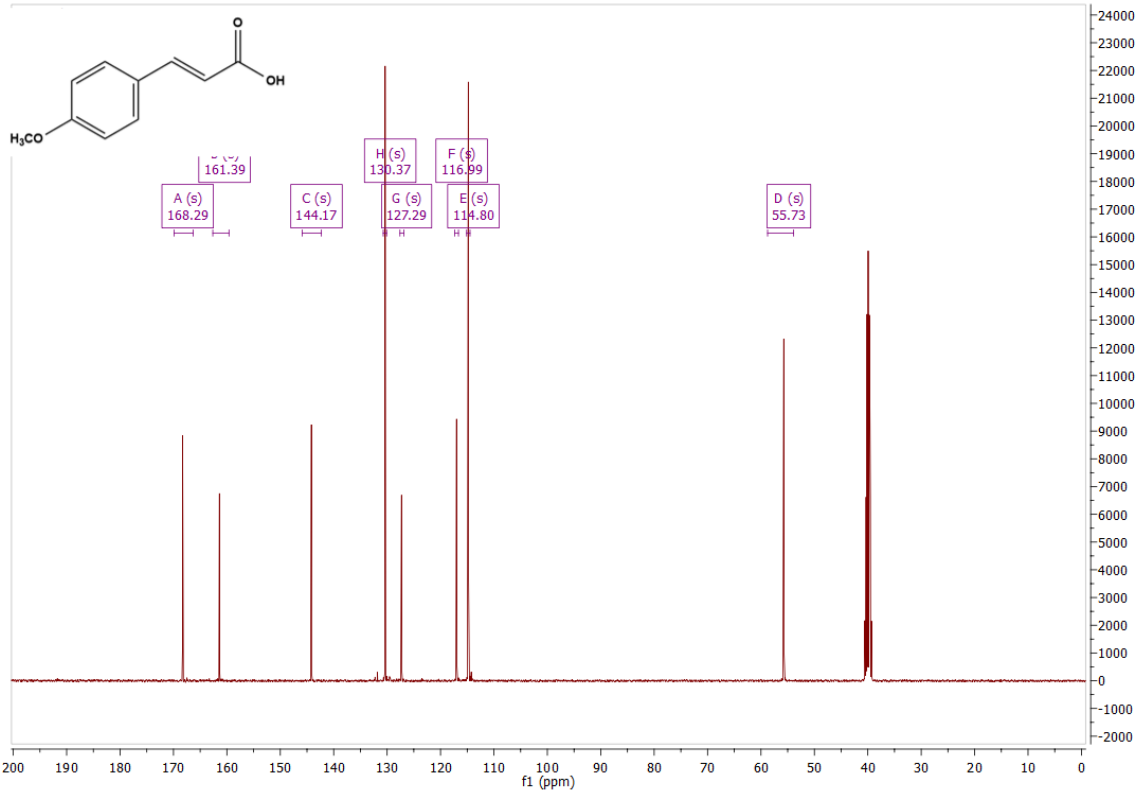


Figure S26. ^{13}C NMR spectrum of 4-methoxycinnamic acid **3e**

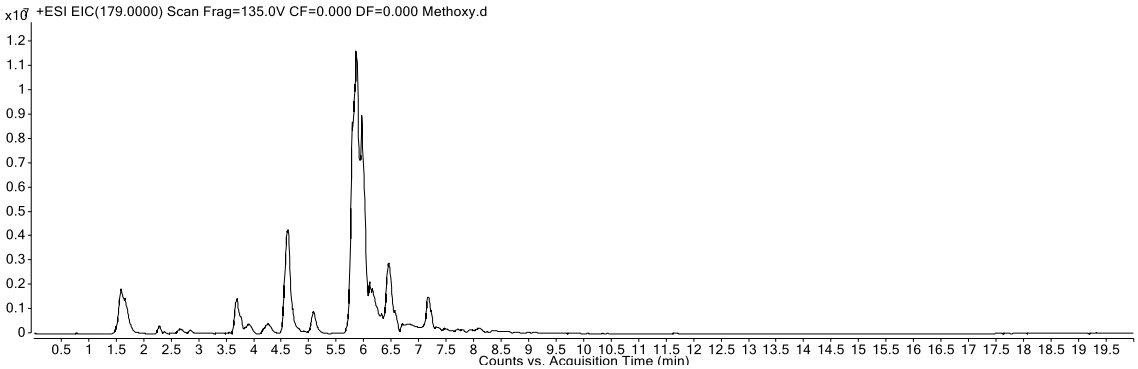


Figure S27. Extracted-ion chromatogram of 4-methoxycinnamic acid (M= 178 g/mol) in positive ion mode identified by $[M+H]^+$ m/z 179

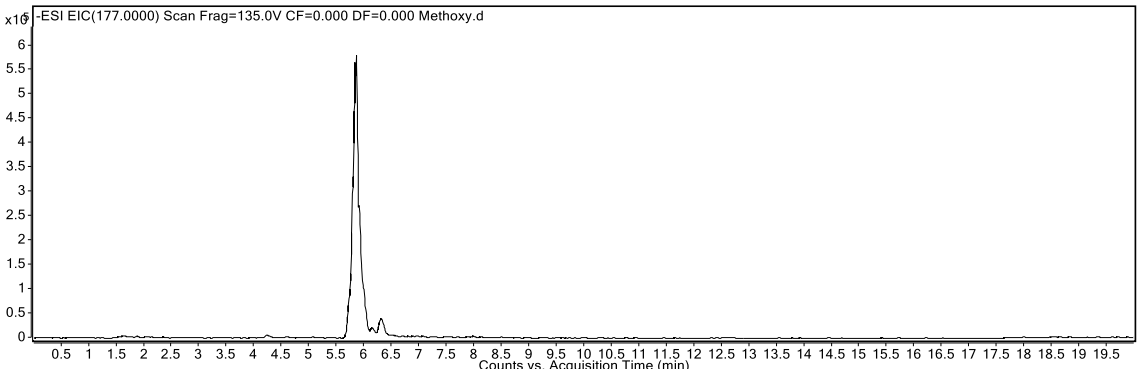


Figure S28. Extracted-ion chromatogram of 4-methoxycinnamic acid (M= 178 g/mol) in negative ion mode identified by $[M–H]^-$ m/z 177

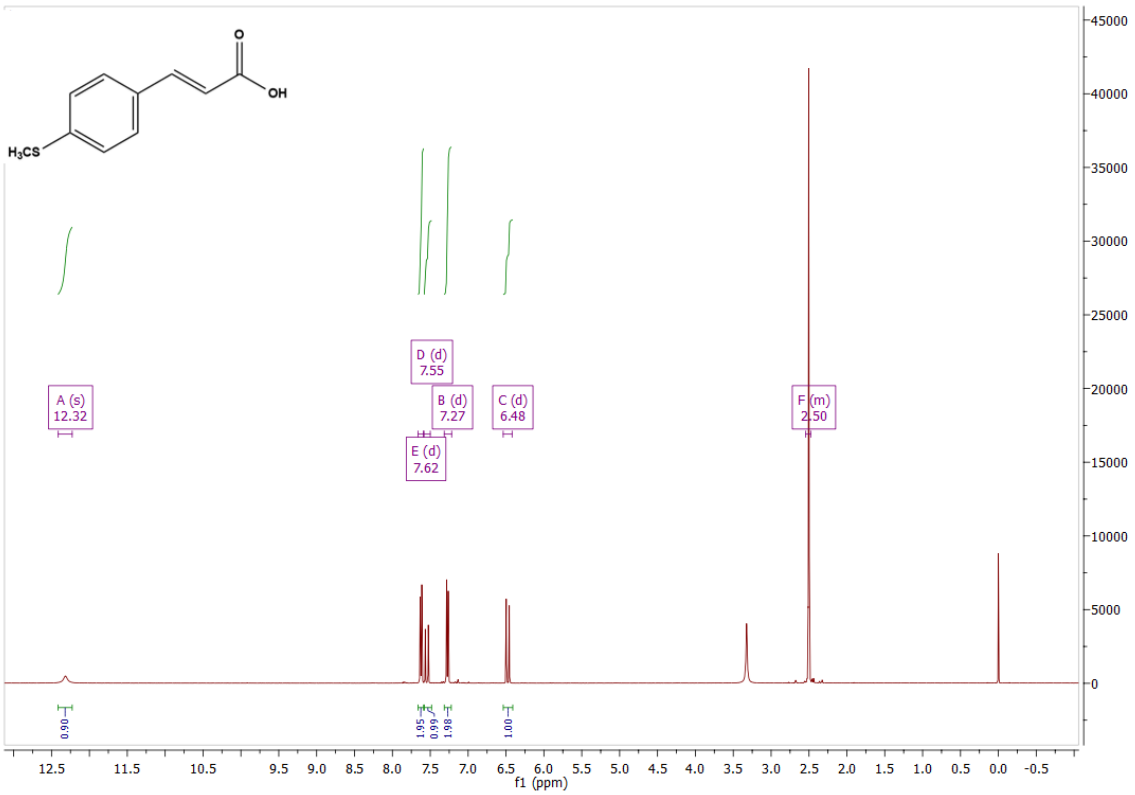


Figure S29. ^{1}H NMR spectrum of 4-(methylthio)cinnamic acid **3f**

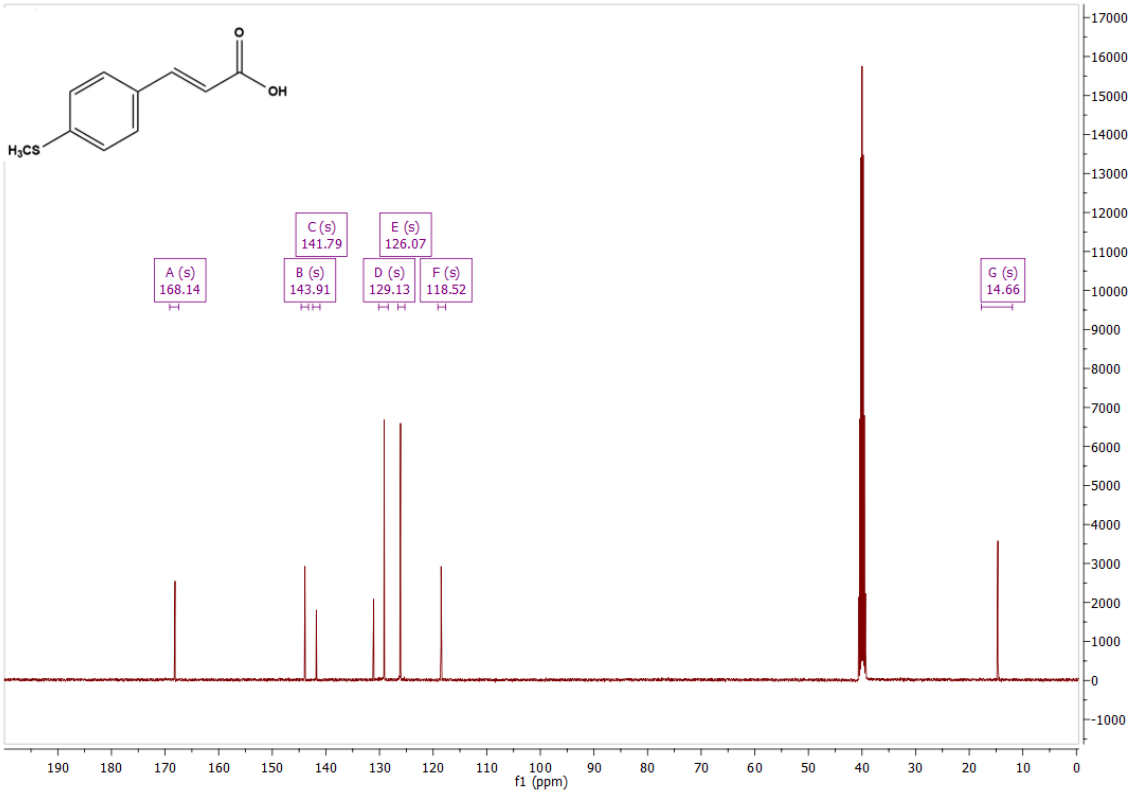


Figure S30. ^{13}C NMR spectrum of 4-(methylthio)cinnamic acid **3f**

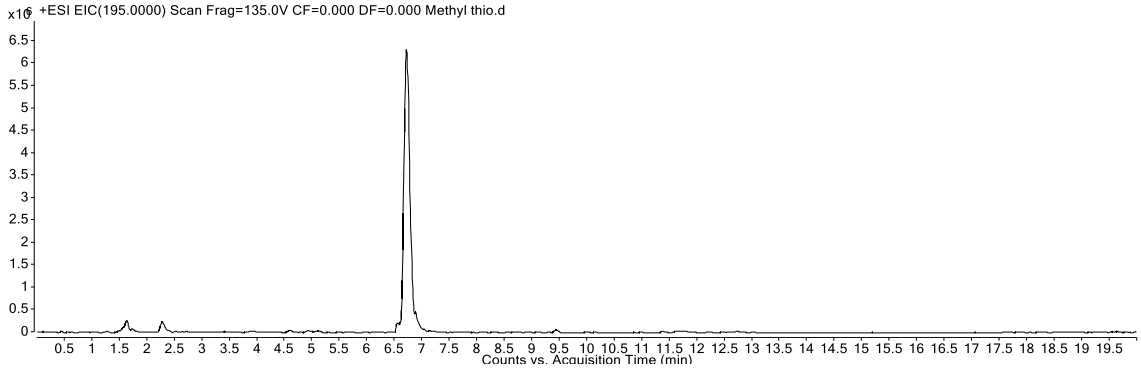


Figure S31. Extracted-ion chromatogram of 4-(methylthio)cinnamic acid (M= 194 g/mol) in positive ion mode identified by $[M+H]^+$ m/z 195

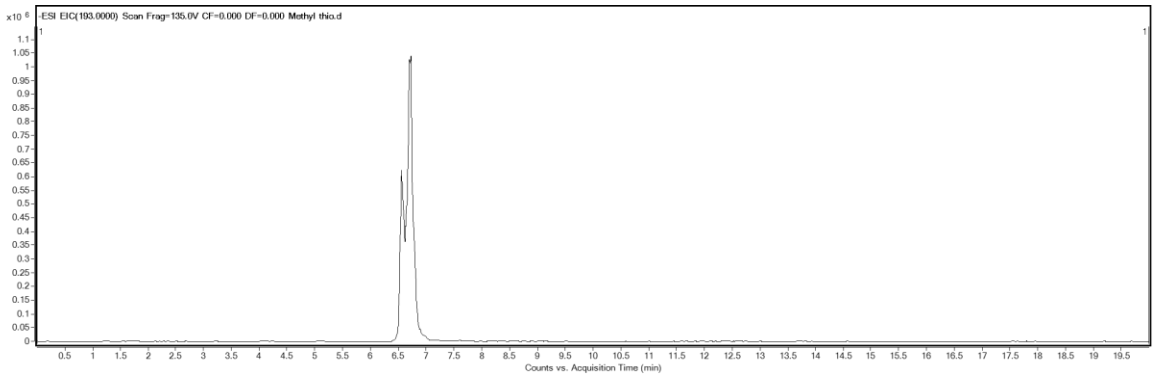


Figure S32. Extracted-ion chromatogram of 4-(methylthio)cinnamic acid (M= 194 g/mol) in negative ion mode identified by $[M–H]^-$ m/z 193

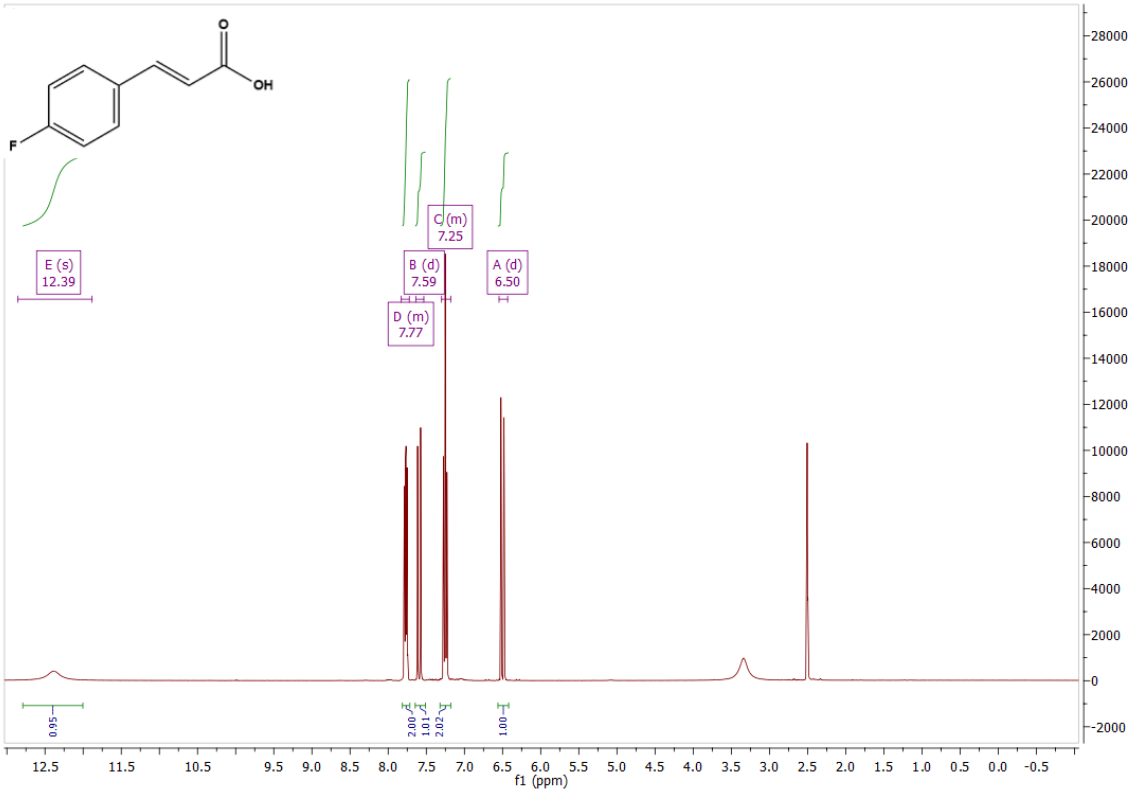


Figure S33. ^{1}H NMR spectrum of 4-fluorocinnamic acid **3g**

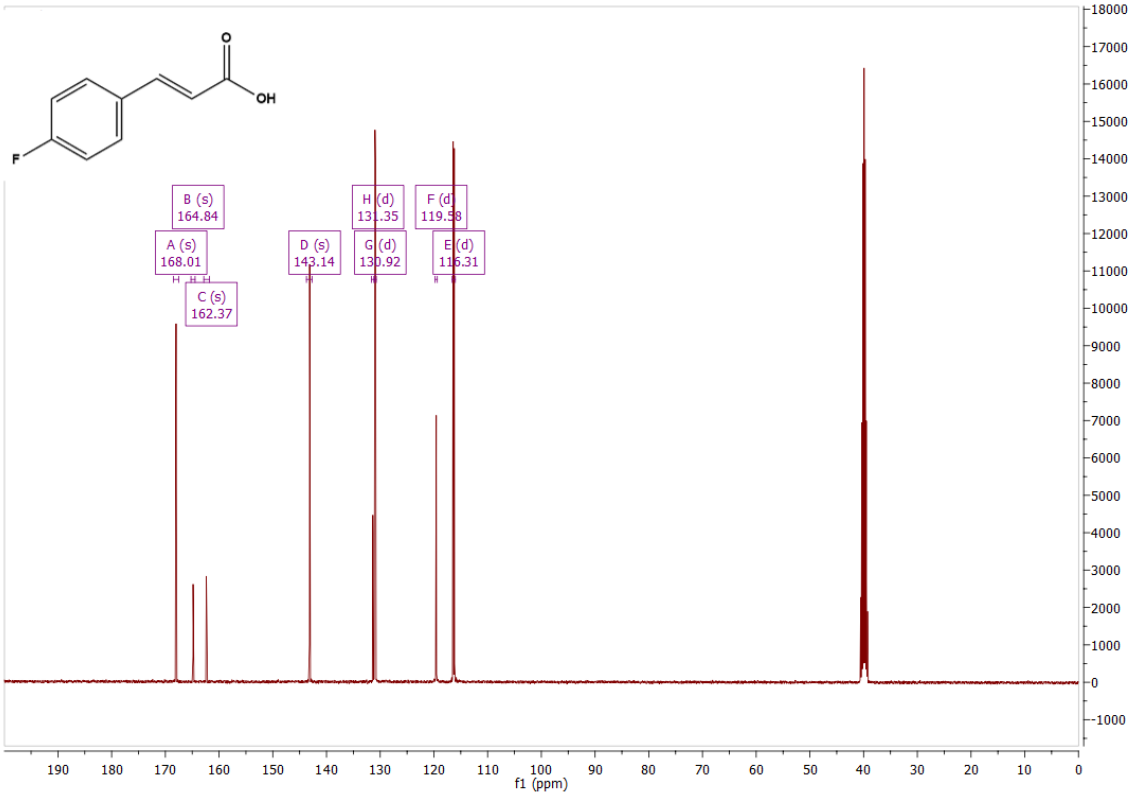


Figure S34. ^{13}C NMR spectrum of 4-fluorocinnamic acid **3g**

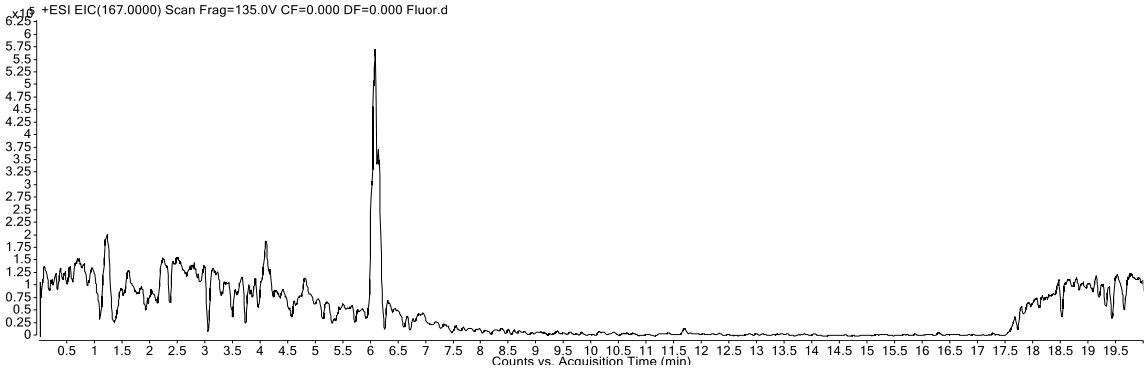


Figure S35. Extracted-ion chromatogram of 4-fluorocinnamic acid (M= 166 g/mol) in positive ion mode identified by $[M+H]^+$ m/z 167

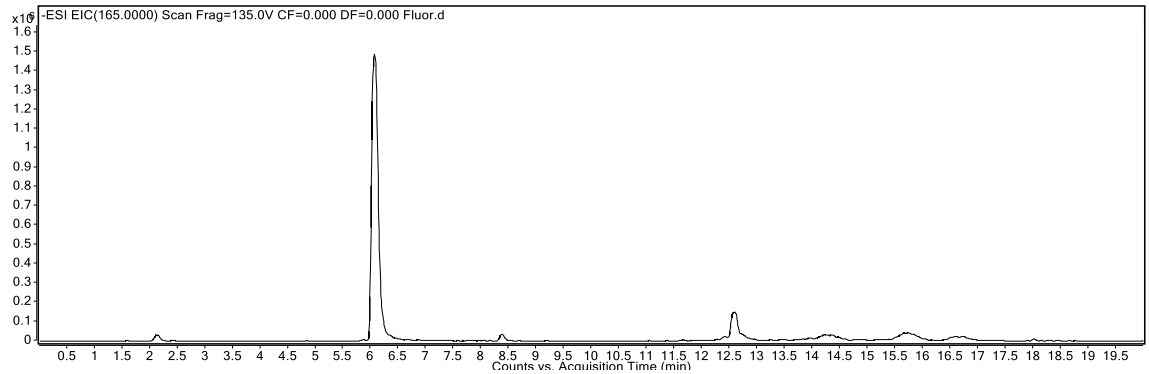


Figure S36. Extracted-ion chromatogram of 4-fluorocinnamic acid (M= 166 g/mol) in negative ion mode identified by $[M–H]^-$ m/z 165

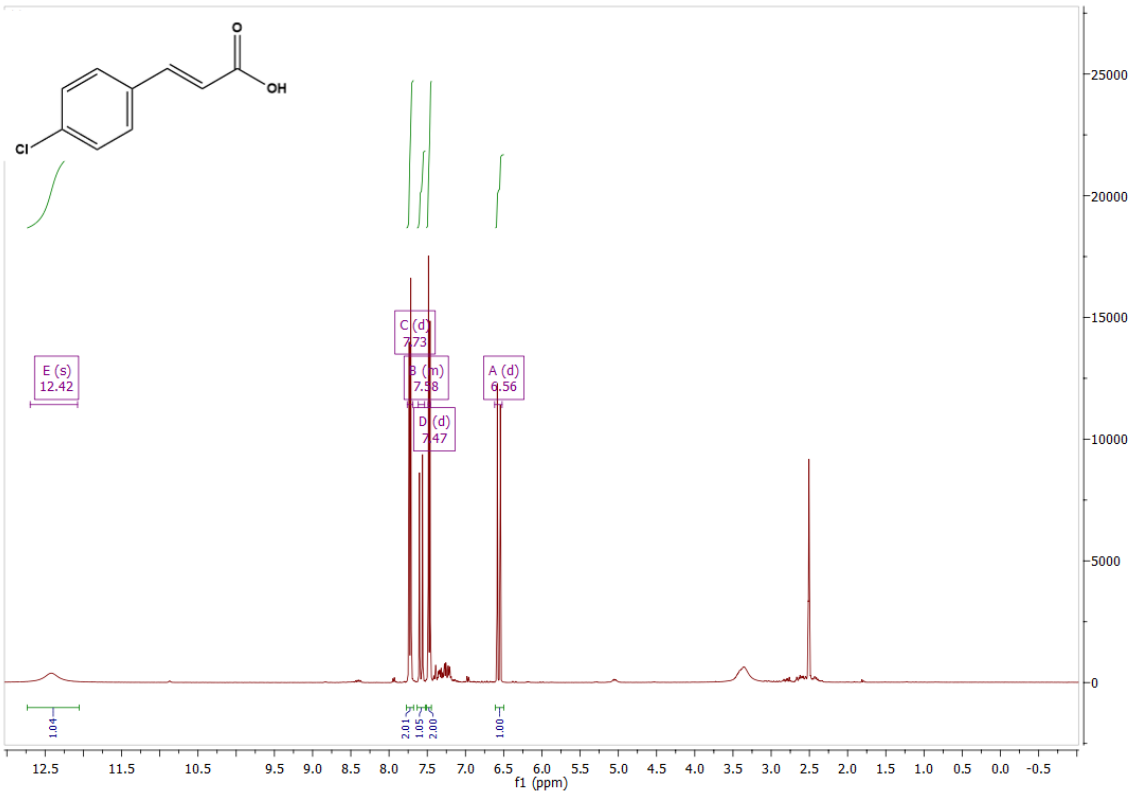


Figure S37. ^{1}H NMR spectrum of 4-chlorocinnamic acid **3h**

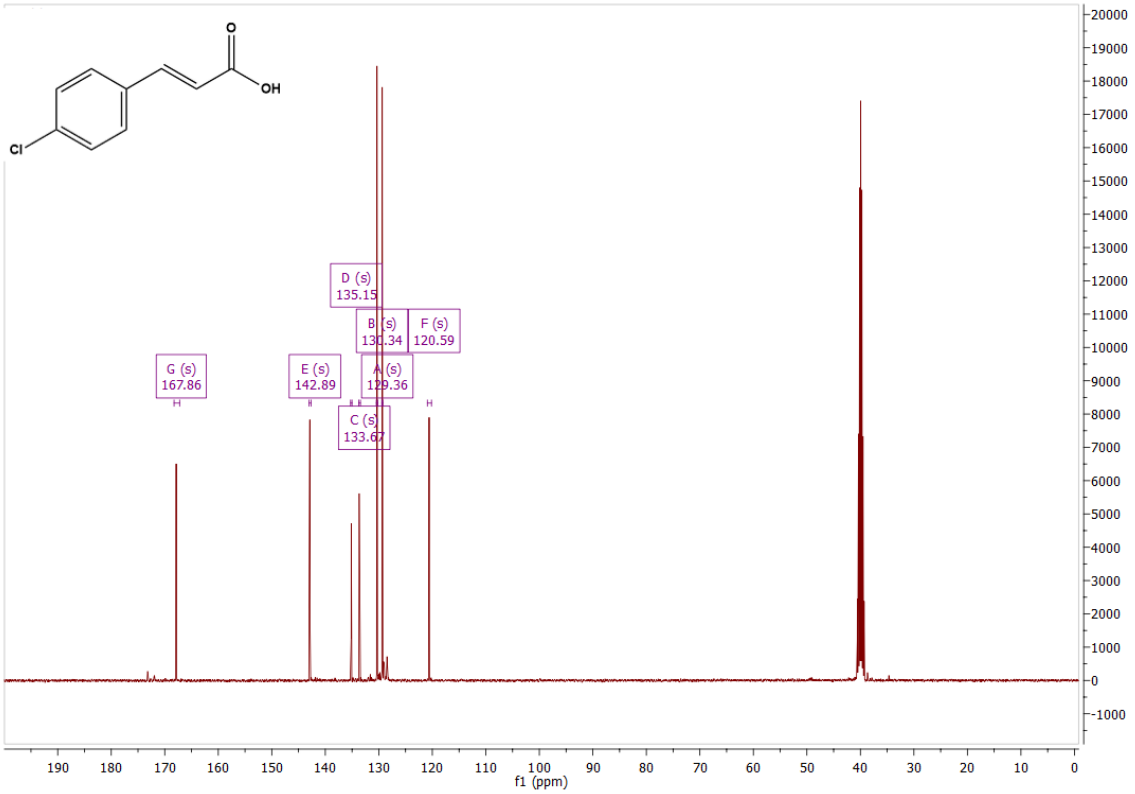


Figure S38. ^{13}C NMR spectrum of 4-chlorocinnamic acid **3h**

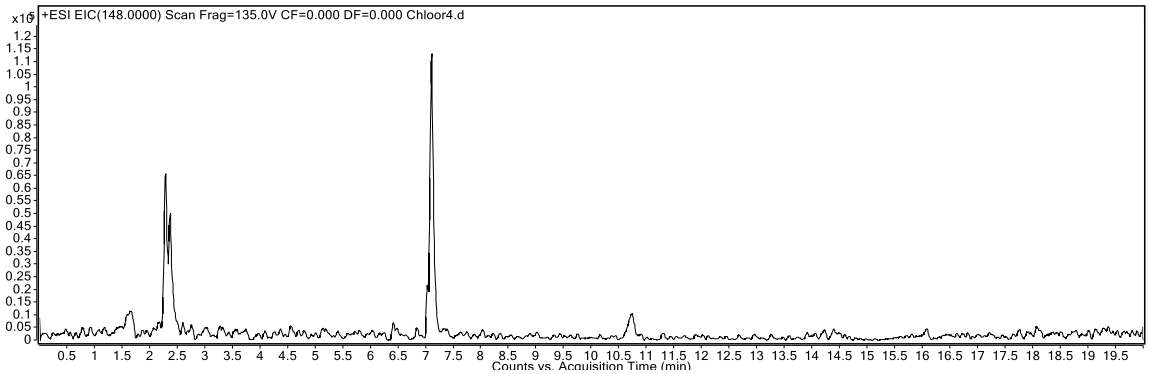


Figure S39. Extracted-ion chromatogram of 4-chlorocinnamic acid (M= 182 and 184 g/mol) in positive ion mode identified by $[M\text{-}Cl^{\bullet}]^{+}$ m/z 148

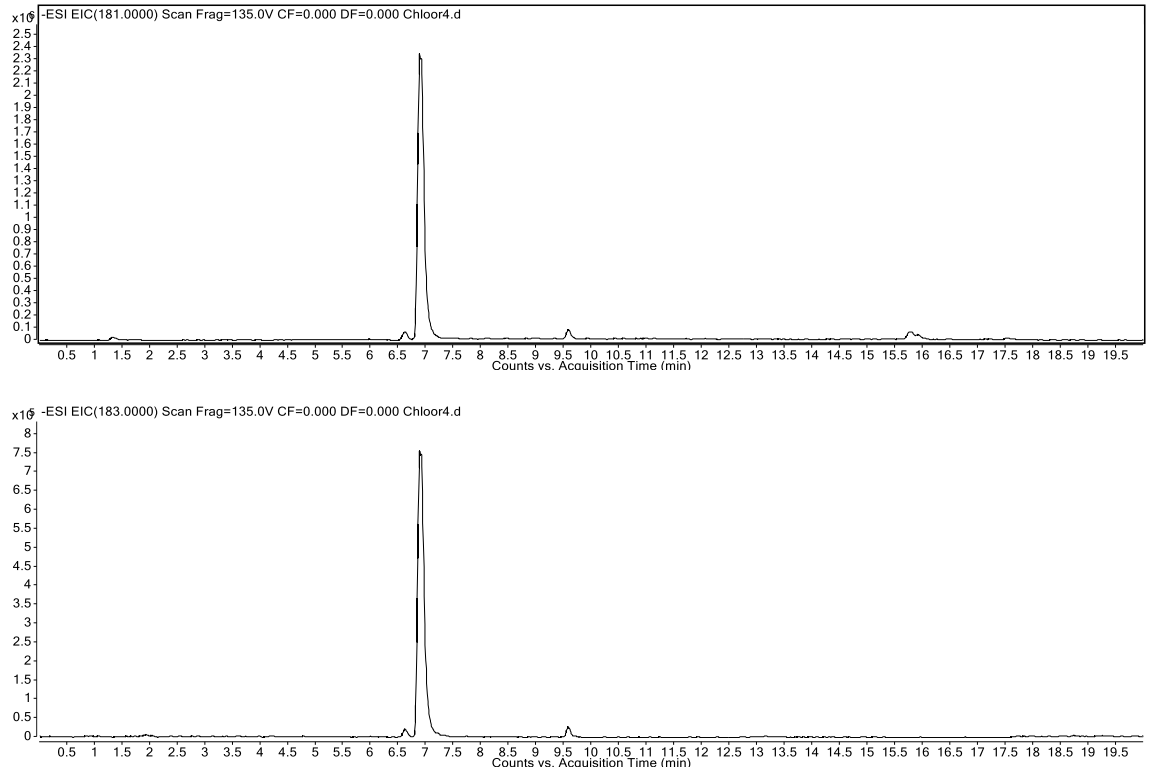


Figure S40. Extracted-ion chromatogram of 4-chlorocinnamic acid (M= 182 and 184 g/mol) in negative ion mode identified by $[M–H]^{-}$ m/z 181 and 183

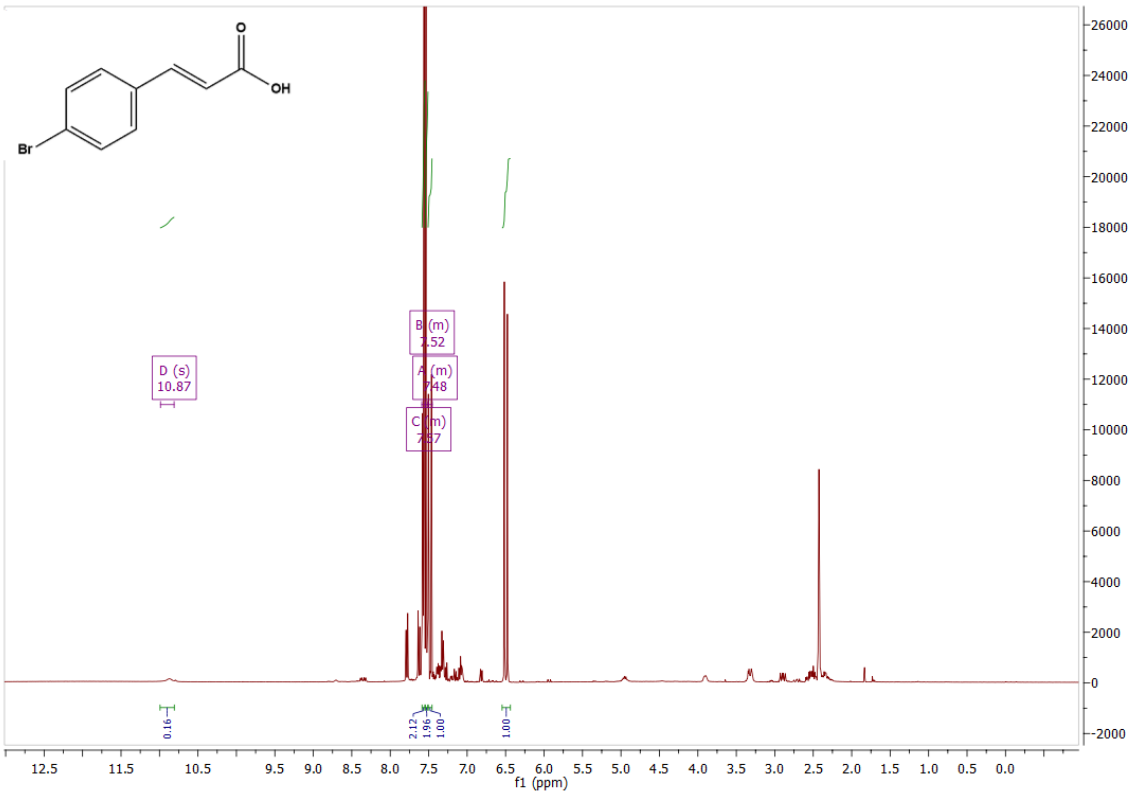


Figure S41. ^{1}H NMR spectrum of 4-bromocinnamic acid **3i**

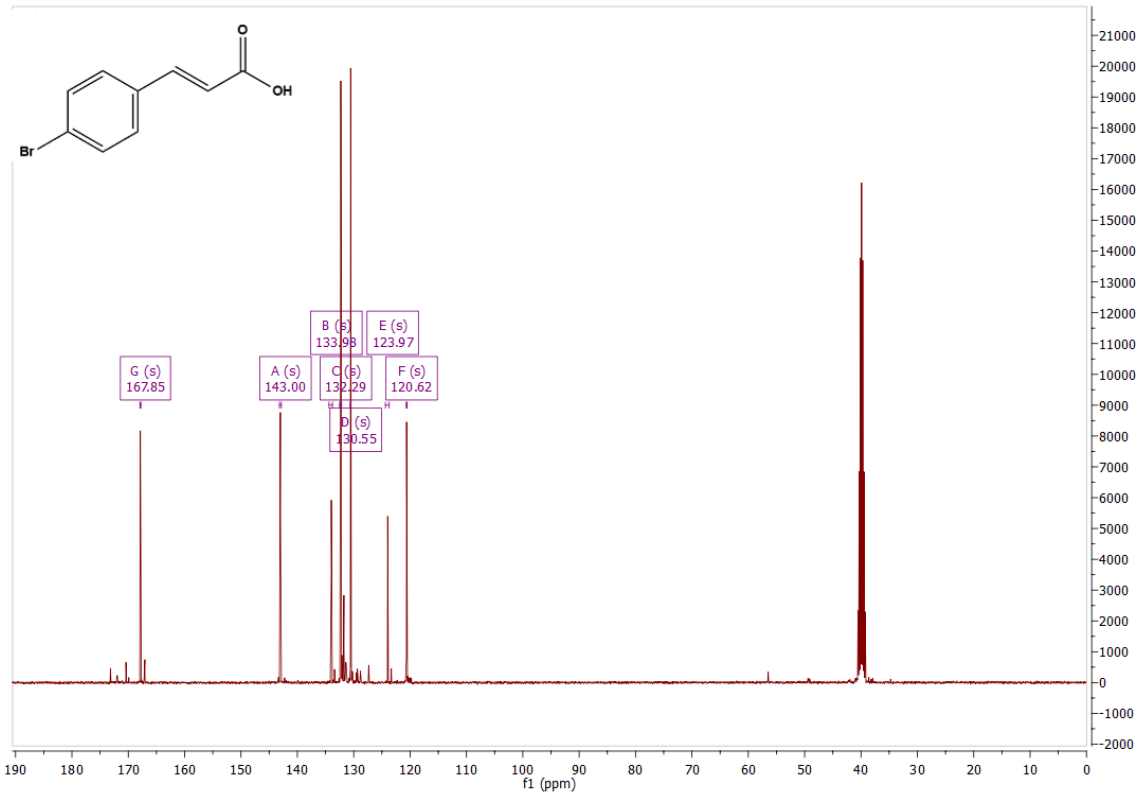


Figure S42. ^{13}C NMR spectrum of 4-bromocinnamic acid **3i**

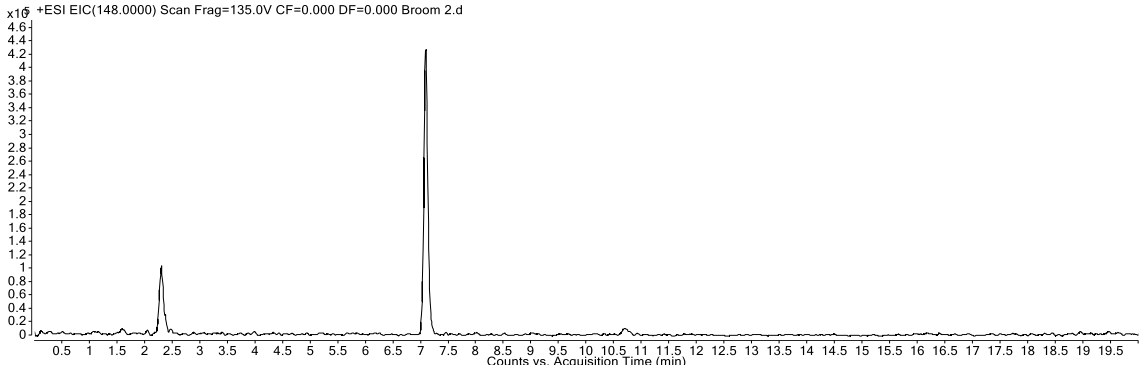


Figure S43. Extracted-ion chromatogram of 4-bromocinnamic acid (M= 226 and 228 g/mol) in positive ion mode identified by $[M\text{-}Br^{\bullet}]^{+}$ m/z 148

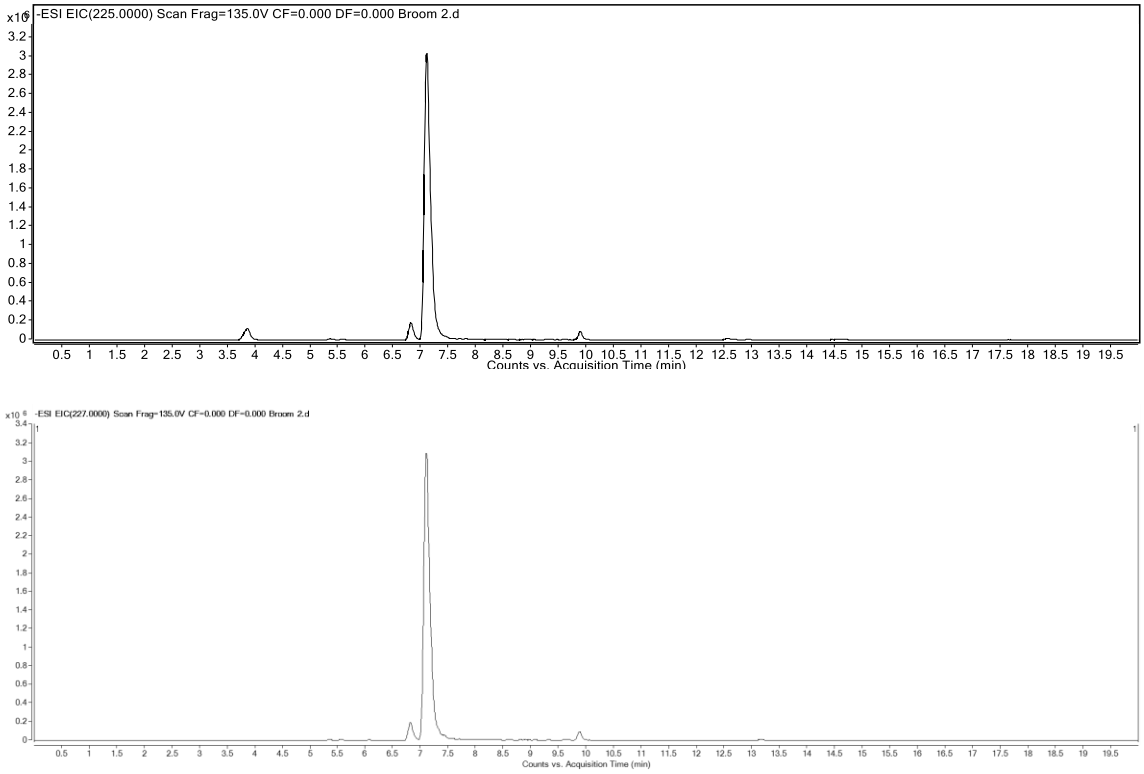


Figure S44. Extracted-ion chromatogram of 4-bromocinnamic acid (M= 226 and 228 g/mol) in negative ion mode identified by $[M–H]^{-}$ m/z 225 and 227

Figure S45. ^{1}H NMR spectrum of p-coumaric acid **3j**

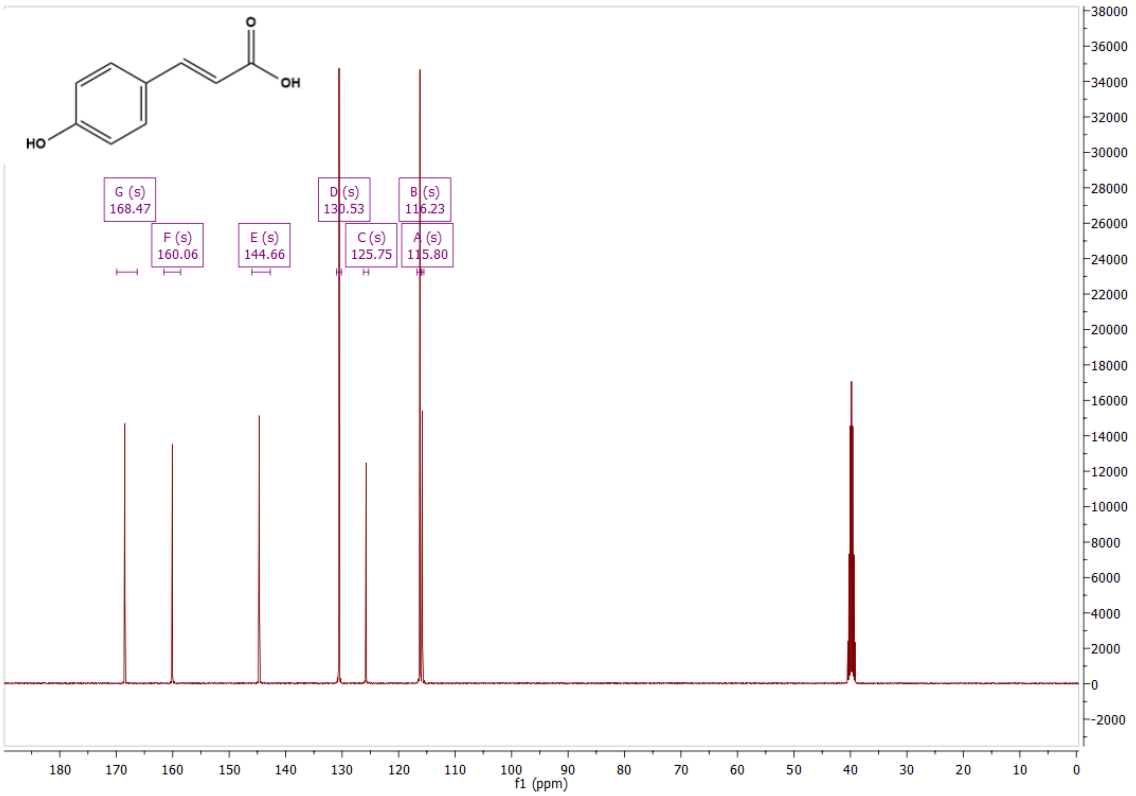


Figure S46. ^{13}C NMR spectrum of p-coumaric acid **3j**

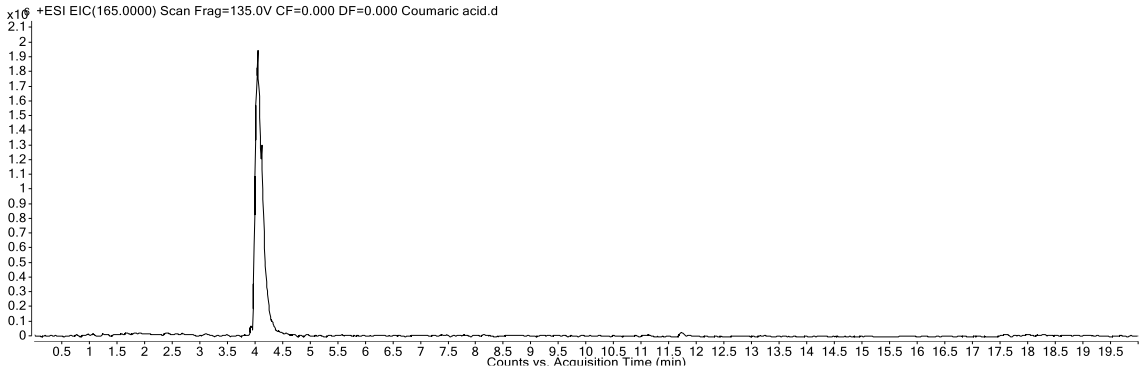


Figure S47. Extracted-ion chromatogram of p-coumaric acid (M= 164 g/mol) in positive ion mode identified by $[M+H]^+$ m/z 165

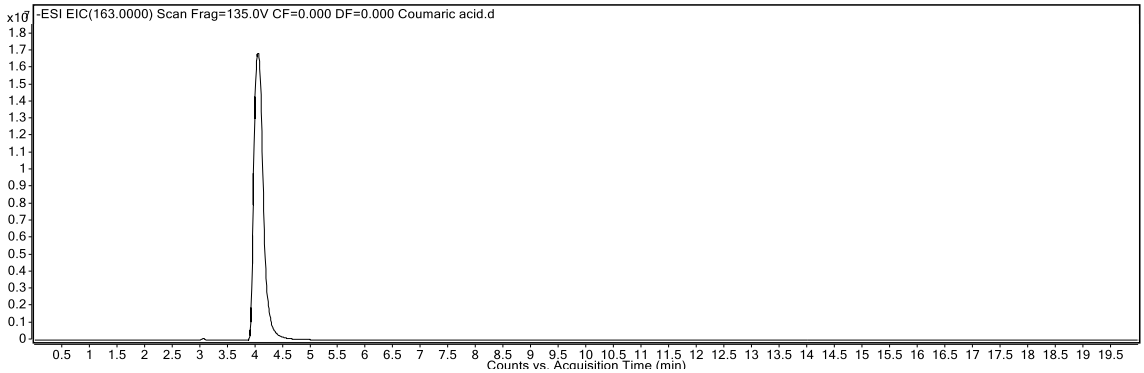


Figure S48. Extracted-ion chromatogram of p-coumaric acid (M= 164 g/mol) in negative ion mode identified by $[M–H]^-$ m/z 163

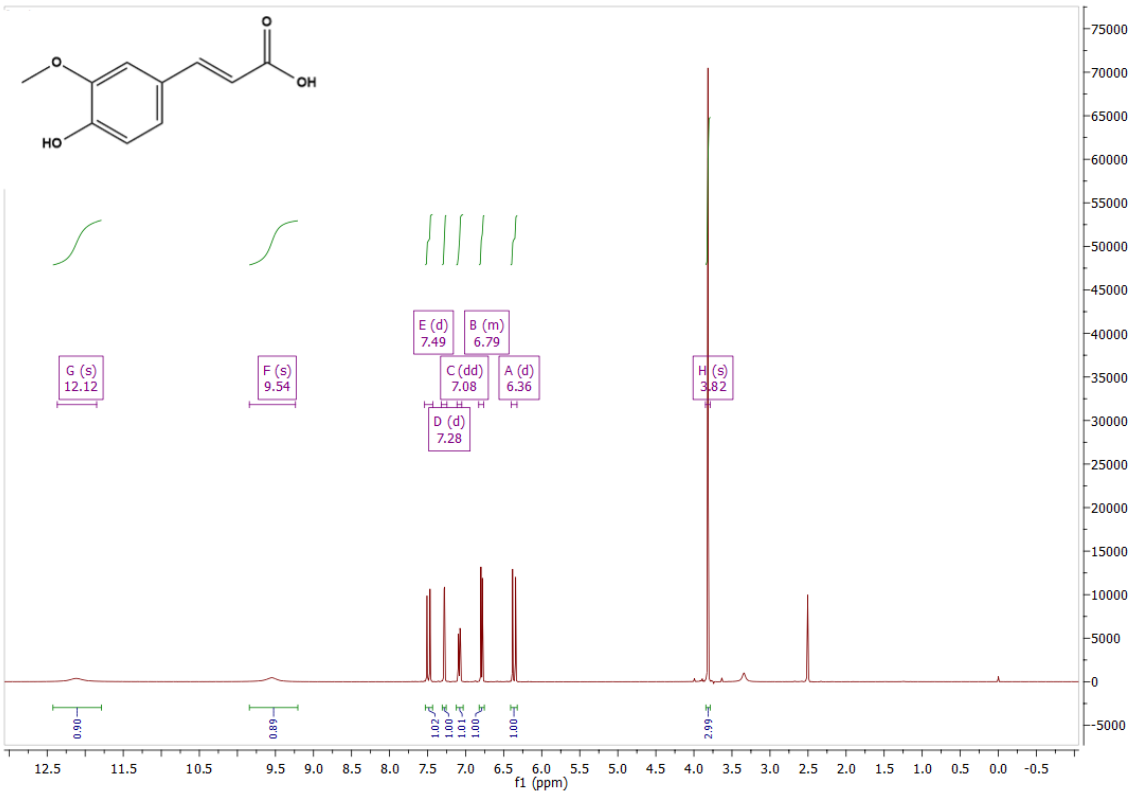


Figure S49. ^{1}H NMR spectrum of ferulic acid **3k**

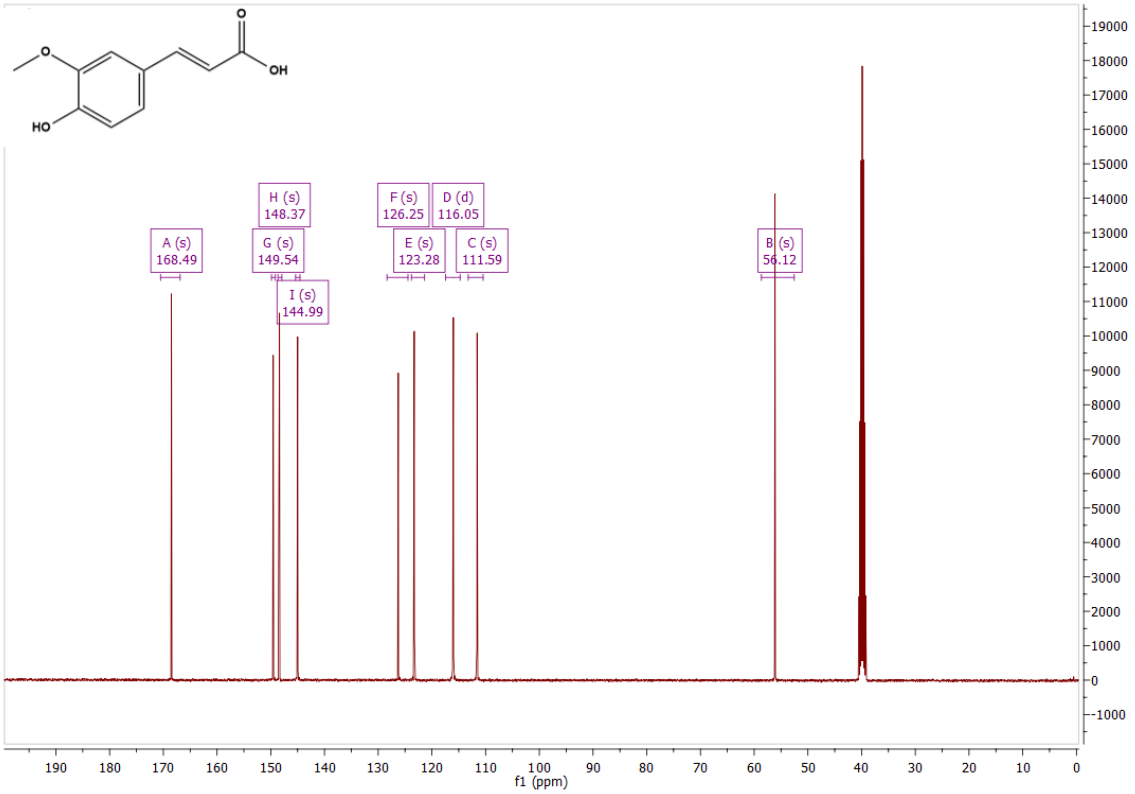


Figure S50. ^{13}C NMR spectrum of ferulic acid **3k**

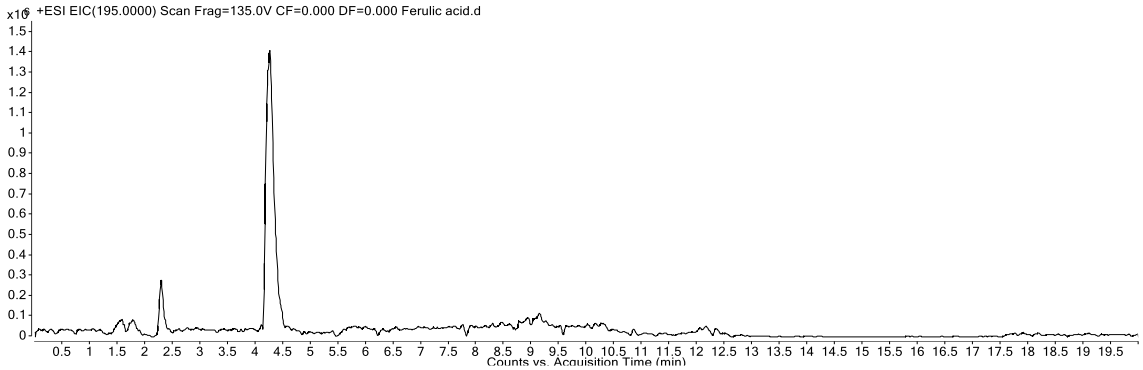


Figure S51. Extracted-ion chromatogram of ferulic acid (M= 194 g/mol) in positive ion mode identified by $[M+H]^+$ m/z 195

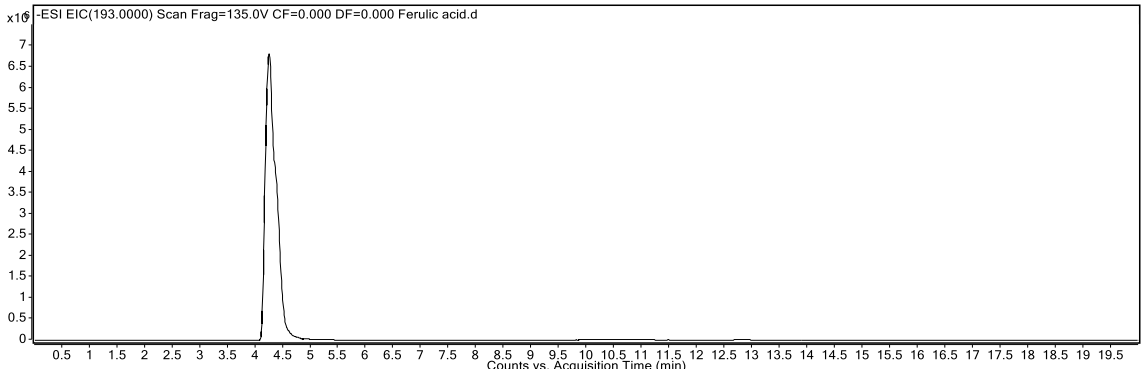


Figure S52. Extracted-ion chromatogram of ferulic acid (M= 194 g/mol) in negative ion mode identified by $[M–H]^-$ m/z 193

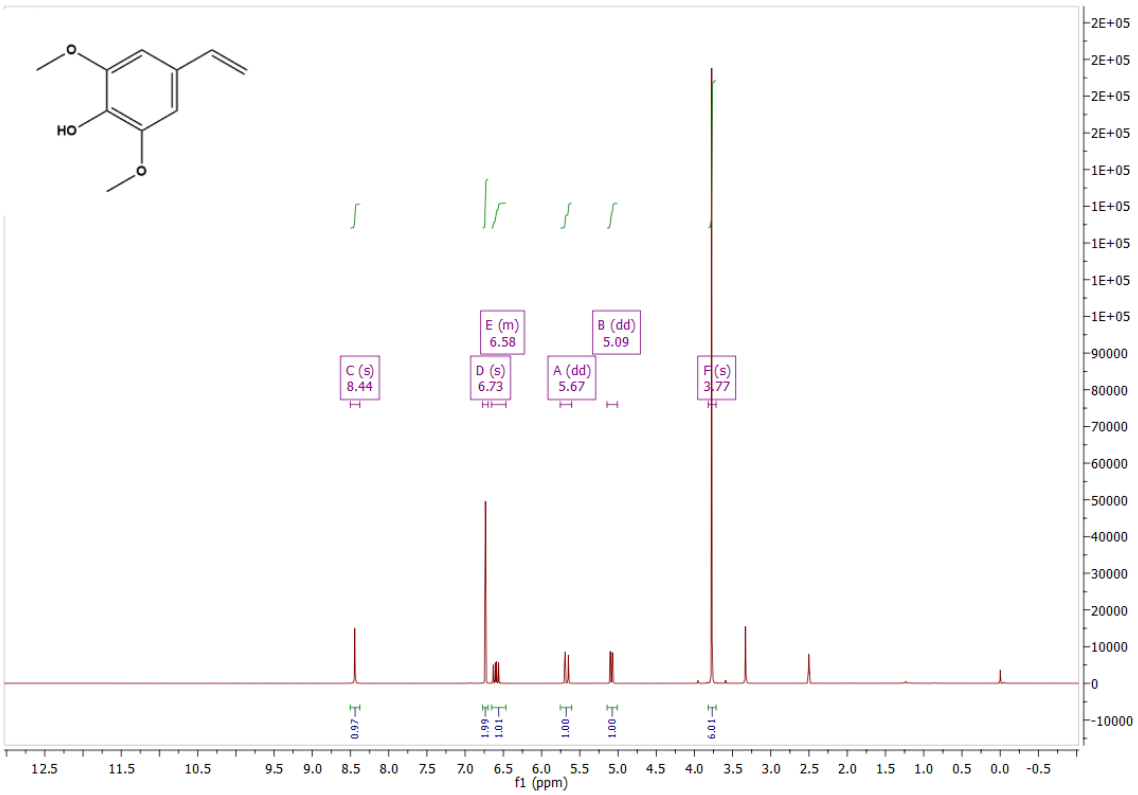


Figure S53. ^{1}H NMR spectrum of 4-vinylsyringol **4a**

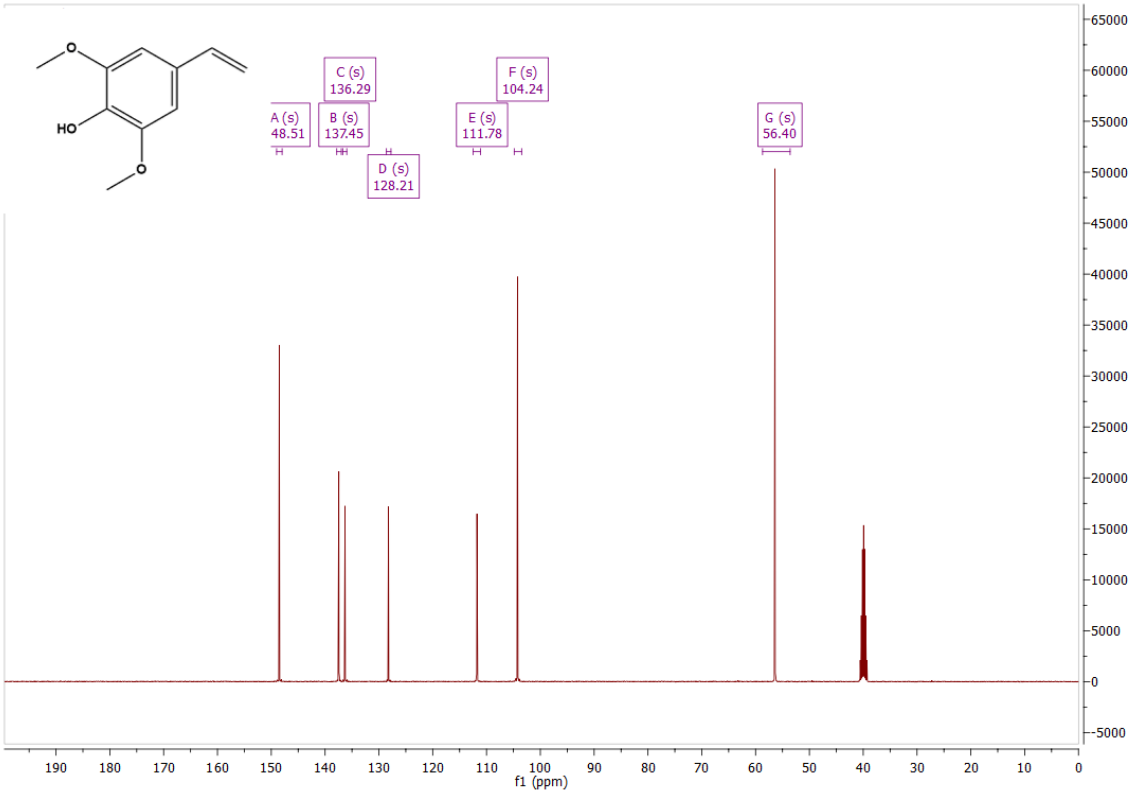


Figure S54. ^{13}C NMR spectrum of 4-vinylsyringol **4a**

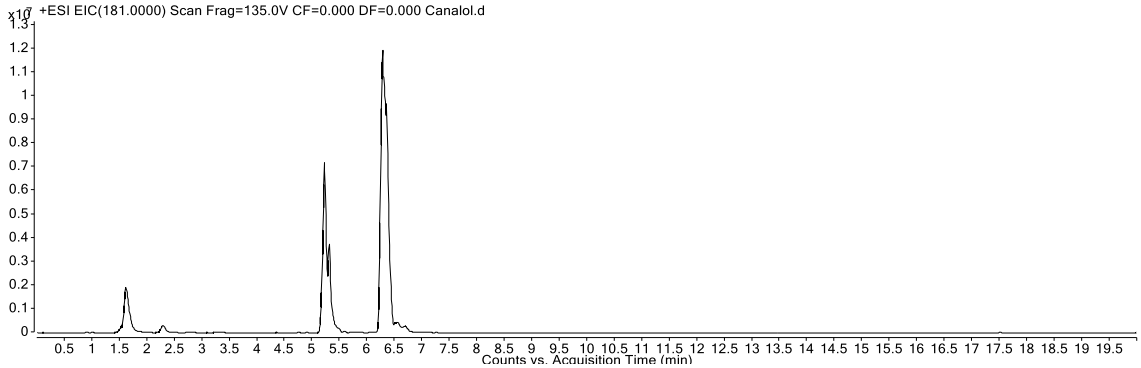


Figure S55. Extracted-ion chromatogram of 4-vinylsyringol (M= 180 g/mol) in positive ion mode identified by $[M+H]^+$ m/z 181

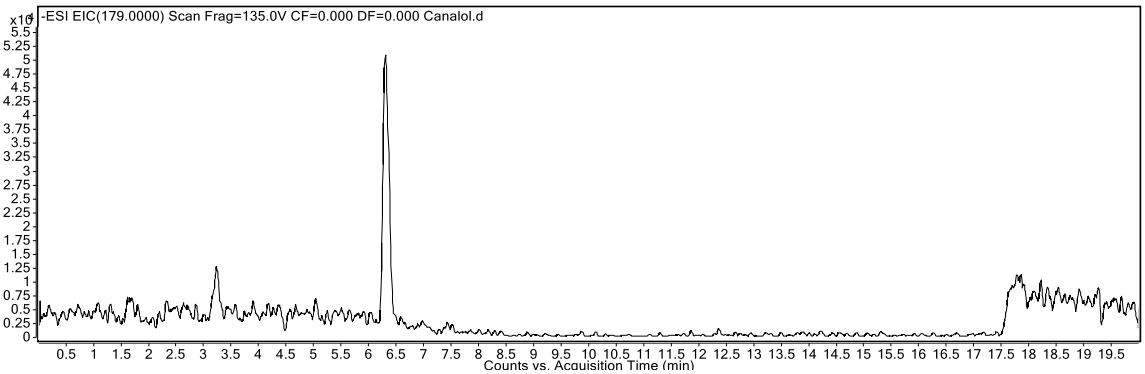


Figure S56. Extracted-ion chromatogram of 4-vinylsyringol (M= 180 g/mol) in negative ion mode identified by $[M–H]^-$ m/z 179