CHAPTER II

EXPERIMENTAL

2.1 Instruments and Equipment

Melting points were determined with a Fisher-Johns melting point apparatus and uncorrected. Thin layer chromatography (TLC) was performed on an aluminium sheet precoated with silica gel (Merck's Kieselgel 60 PF_{254}). Column chromatography was performed on silica gel (Merck's Kieselgel 60G) (Merck KgaA, Darmstadt, Germany).

The IR spectra were recorded on Nicolet Fourier Transform Infrared Spectrophotometer: Impact 410 (Nicolet Instrument Technologies, Inc., WI, USA). Solid samples were incorporated into a pellet of potassium bromide. Liquid samples were dropped on sodium chloride cells. The ^{1}H- and ^{13}C-NMR spectra were performed in deuterated chloroform ($CDCl_3$) with tetramethylsilane (TMS) as an internal reference on Varian Nuclear Magnetic Resonance Spectrometer; model Mercury plus 400 NMR Spectrometer which operated at 399.84 MHz for ^{1}H and 100.54 MHz for ^{13}C nuclei. The chemical shifts (δ) are assigned by comparison with residue solvent protons.

2.2 Chemicals

All solvents used in this research were purified prior to use by standard methodology except for those which were reagent grade. The reagents used for synthesizing the precursors were purchased from Fluka chemical company or otherwise stated and were used without further purification.

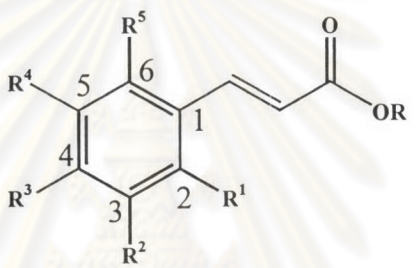
2.3 Synthesis of Substituted *trans*-Cinnamic Acid Derivatives

2.3.1 Synthesis of *trans*-Cinnamate Esters

General Procedure[22]

Substituted cinnamic acids (0.001 mol) and selected alcohol (0.01 mol) were added into the round bottom flask, then 0.03 mL of concentrated sulfuric acid was dropped. The mixture was refluxed for 5 hours. After that the mixture was extracted twice with 10 mL of diethyl ether. The combined extracts were washed twice by $NaHCO_3$, dried over Na_2SO_4 anhydrous, evaporated in vacuum and the residue was fractionally distilled to give the desired compound.

Fifty substituted cinnamate esters were synthesized and sixty-five substituted cinnamate esters structures are displayed as shown in Figure 2.1.



Cpds	R	R^1	R^2	R^3	R^4	R^5
S00	CH_2CH_3	H	H	H	H	H
S01	CH_2CH_3	H	**F**	H	H	H
S02	CH_2CH_3	H	H	**F**	H	H
S03	CH_2CH_3	**Cl**	H	H	H	H
S04	CH_2CH_3	H	**Cl**	H	H	H
S05	CH_2CH_3	H	H	**Cl**	H	H
S06	CH_2CH_3	**Br**	H	H	H	H
S07	CH_2CH_3	H	**Br**	H	H	H
S08	CH_2CH_3	H	H	**Br**	H	H
S09	CH_2CH_3	**Cl**	H	**Cl**	H	H
S10	CH_2CH_3	**Cl**	H	H	H	**Cl**
S11	CH_2CH_3	H	**Cl**	**Cl**	H	H
S12	CH_2CH_3	**Cl**	H	H	H	**F**

Figure 2.1 Structures of synthesized substituted cinnamate esters

Cpds	R	R^1	R^2	R^3	R^4	R^5
S13	CH_2CH_3	**OCH_3**	H	H	H	H
S14	CH_2CH_3	H	**OCH_3**	H	H	H
S15	CH_2CH_3	H	H	**OCH_3**	H	H
S16	CH_2CH_3	H	H	**OC_4H_9**	H	H
S17	CH_2CH_3	H	H	**OC_6H_{13}**	H	H
S18	CH_2CH_3	H	H	**OC_8H_{17}**	H	H
S19	CH_2CH_3	H	H	**$OC_{12}H_{25}$**	H	H
S20	CH_2CH_3	H	H	**OBn**	H	H
S21	CH_2CH_3	H	H	**OPh**	H	H
S22	CH_2CH_3	H	**OCH_3**	**OC_4H_9**	H	H
S23	CH_2CH_3	H	**OCH_3**	**OC_6H_{13}**	H	H
S24	CH_2CH_3	H	**OCH_3**	**OC_8H_{17}**	H	H
S25	CH_2CH_3	H	**OCH_3**	**$OC_{12}H_{25}$**	H	H
S26	CH_2CH_3	H	**OCH_3**	**OBn**	H	H
S27	CH_2CH_3	**OCH_3**	**OCH_3**	H	H	H
S28	CH_2CH_3	**OCH_3**	H	**OCH_3**	H	H
S29	CH_2CH_3	**OCH_3**	H	H	**OCH_3**	H
S30	CH_2CH_3	H	**OCH_3**	**OCH_3**	H	H
S31	CH_2CH_3	H	**OCH_3**	H	**OCH_3**	H
S32	CH_2CH_3	H	**OCH_3**	**OCH_3**	**OCH_3**	H
S33*	CH_2CH_3	H	**OCH_2O**		H	H
S34*	CH_2CH_3	**NO_2**	H	H	H	H
S35*	CH_2CH_3	H	**NO_2**	H	H	H
S36	CH_2CH_3	H	H	**NO_2**	H	H
S37	CH_2CH_3	**Cl**	H	H	**NO_2**	H
S38	CH_2CH_3	H	**NO_2**	**Cl**	H	H
S39	CH_2CH_3	**NO_2**	H	H	**Cl**	H
S40	CH_2CH_3	H	H	**CH_3**	H	H
S41	CH_2CH_3	H	H	**$CH(CH_3)_2$**	H	H
S42	CH_2CH_3	H	H	**$C(CH_3)_3$**	H	H
S43	CH_2CH_3	H	H	**CF_3**	H	H

Figure 2.1 (cont.)

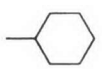
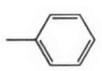
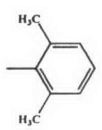
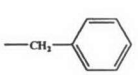
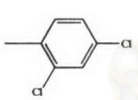
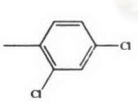
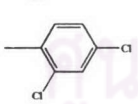
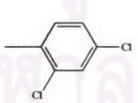
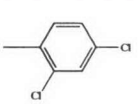
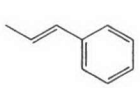
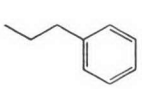
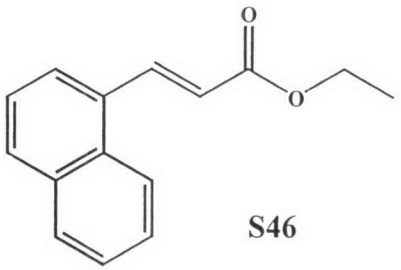
Cpds	R	R^1	R^2	R^3	R^4	R^5
S44	CH_2CH_3	H	**CN**	H	H	H
S45	CH_2CH_3	H	H	**CN**	H	H
S47	CH_3	H	H	H	H	H
S48	CH_3	**Cl**	H	H	H	H
S49	CH_3	H	H	**CH_3**	H	H
S50	CH_3	H	H	**OCH_3**	H	H
S51	$(CH_2)_3CH_3$	H	H	H	H	H
S52	$(CH_2)_3CH_3$	**Cl**	H	H	H	H
S53*	$(CH_2)_3CH_3$	H	H	**CH_3**	H	H
S54*		H	H	**CH_3**	H	H
S55*		H	H	**CH_3**	H	H
S56*		H	H	**CH_3**	H	H
S57*		H	H	**CH_3**	H	H
S58*		H	H	**CH_3**	H	H
S59*		H	H	**C_3H_7**	H	H
S60*		**NO_2**	H	H	H	H
S61*		H	**NO_2**	H	H	H
S62*		H	**OCH_2O**		H	H
S63**		H	H	H	H	H
S64**		H	H	H	H	H

Figure 2.1 (cont.)



S46

Figure 2.1 (cont.)

*These compounds were kindly donated from Ms. Sujittra Deesamer.[17]

Ethyl cinnamate (**S00**): Yellow liquid (79 %), R_f 0.73 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.69 (*d*, *J* = 15.83 Hz, 1H, Ar-C**H**=), 7.53-7.37 (Ar-**H**, 5H), 6.44 (*d*, *J* = 15.83 Hz, 1H, =C**H**-COOR), 4.26 (*q*, *J* = 7.04 Hz, 2H, -OC**H**$_2$-) and 1.34 (*t*, *J* = 7.04 Hz, 3H, -C**H**$_3$).

Ethyl 3-fluorocinnamate (**S01**): Pale yellow liquid (72 %), R_f 0.68 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.67 (*d*, *J* = 15.83 Hz, 1H, Ar-C**H**=), 7.42-7.07 (Ar-**H**, 4H), 6.46 (*d*, *J* = 15.83 Hz, 1H, =C**H**-COOR), 4.31 (*q*, *J* = 7.62 Hz, 2H, -OC**H**$_2$-) and 1.38 (*t*, *J* = 7.04 Hz, 3H, -C**H**$_3$).

Ethyl 4-fluorocinnamate (**S02**): Pale yellow liquid (82 %), R_f 0.70 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.68 (*d*, *J* = 15.83 Hz, 1H, Ar-C**H**=), 7.55 (*dd*, *J* = 8.80, 8.21 Hz, 2H, Ar-**H**), 7.11 (*t*, *J* = 8.80 Hz, 2H, Ar-**H**), 6.40 (*d*, *J* = 15.83 Hz, 1H, =C**H**-COOR), 4.30 (*q*, *J* = 7.04 Hz, 2H, -OC**H**$_2$-) and 1.37 (*t*, *J* = 7.04 Hz, 3H, -C**H**$_3$).

Ethyl 2-chlorocinnamate (**S03**): Pale yellow liquid (65 %), R_f 0.66 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 8.13 (*d*, *J* = 16.40 Hz, 1H, Ar-C**H**=), 7.66 (*d*, *J* = 8.79 Hz, 1H, Ar-**H**), 7.45 (*d*, *J* = 7.03 Hz, 1H, Ar-**H**), 7.34-7.30 (Ar-**H**, 2H), 6.47 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 4.32 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-) and 1.38 (*t*, *J* = 7.62 Hz, 3H, -C**H**$_3$).

Ethyl 3-chlorocinnamate (**S04**): Pale yellow liquid (46 %), R_f 0.69 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.65 (*d*, *J* = 16.40 Hz, 1H, Ar-C**H**=), 7.54 (*s*, 1H, Ar-**H**), 7.44-7.35 (Ar-**H**, 3H), 6.47 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.30 (*q*, *J* = 7.62 Hz, 2H, -OC**H**$_2$-) and 1.37 (*t*, *J* = 7.62 Hz, 3H, -C**H**$_3$).

Ethyl 4-chlorocinnamate (**S05**): Pale yellow liquid (38 %), R_f 0.73 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.67 (*d*, *J* = 15.83 Hz, 1H, Ar-C**H**=), 7.49 (*d*, *J* = 8.80 Hz, 2H, Ar-**H**), 7.39 (*d*, *J* = 8.21 Hz, 2H, Ar-**H**), 6.44 (*d*, *J*

= 15.83 Hz, 1H, =C**H**-COOR), 4.30 (*q*, *J* = 7.62 Hz, 2H, -OC**H**$_2$-) and 1.37 (*t*, *J* = 7.04 Hz, 3H, -C**H**$_3$).

Ethyl 2-bromocinnamate (**S06**): Pale yellow liquid (56 %), R_f 0.63 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 8.08 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.64 (*dd*, *J* = 8.20, 7.62 Hz, 2H, Ar-**H**), 7.36 (*t*, *J* = 8.20 Hz, 1H, Ar-**H**), 7.26 (*t*, *J* = 7.62 Hz, 1H, Ar-**H**), 6.42 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 4.32 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-) and 1.38 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 3-bromocinnamate (**S07**): Pale yellow liquid (68 %), R_f 0.68 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.70 (*s*, 1H, Ar-**H**), 7.63 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.54 (*d*, *J* = 8.20 Hz, 1H, Ar-**H**), 7.47 (*d*, *J* = 7.62 Hz, 1H, Ar-**H**), 7.30 (*t*, *J* = 7.03 Hz, 1H, Ar-**H**), 6.46 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 4.30 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-) and 1.37 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 4-bromocinnamate (**S08**): Pale yellow liquid (76 %), R_f 0.69 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.65 (*d*, *J* = 16.42 Hz, 1H, Ar-C**H**=), 7.55 (*d*, *J* = 8.21 Hz, 2H, Ar-**H**), 7.42 (*d*, *J* = 8.80 Hz, 2H, Ar-**H**), 6.46 (*d*, *J* = 15.83 Hz, 1H, =C**H**-COOR), 4.30 (*q*, *J* = 7.04 Hz, 2H, -OC**H**$_2$-) and 1.37 (*t*, *J* = 7.04 Hz, 3H, -C**H**$_3$).

Ethyl 2,4-dichlorocinnamate (**S09**): Yellow viscous oil (80 %), R_f 0.70 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 8.03 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.58 (*d*, *J* = 8.79 Hz, 2H, Ar-**H**), 7.47 (*s*, 1H, Ar-**H**), 6.44 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.31 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-) and 1.37 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 2,6-dichlorocinnamate (**S10**): Yellow liquid (84 %), R_f 0.60 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.81 (*d*, *J* = 16.40 Hz, 1H, Ar-C**H**=), 7.38 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 7.21 (*t*, *J* = 8.20 Hz, 1H, Ar-**H**), 6.62 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.32 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-) and 1.38 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 3,4-dichlorocinnamate (**S11**): Yellow viscous oil (84 %), R_f 0.60 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.61 (*s*, 1H, Ar-**H**), 7.57 (*d*, *J* = 16.40 Hz, 1H, Ar-C**H**=), 7.46 (*d*, *J* = 8.20 Hz, 1H, Ar-**H**), 7.35 (*d*, *J* = 8.20 Hz, 1H, Ar-**H**), 6.42 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.27 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-) and 1.34 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 2-chloro-6-fluorocinnamate (**S12**): Brown liquid (73 %), R_f 0.65 (hexane/ethyl acetate 50%); IR (neat, cm^{-1}): 3081, 2984, 2937, 1715, 1637, 1602, 1567, 1450, 1369, 1310, 1271 and 1174; ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.91 (*d*, *J* = 16.40 Hz, 1H, Ar-C**H**=), 7.27-7.06 (Ar-**H**, 3H), 6.73 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.30 (*q*, *J* = 6.44 Hz, 2H, -OC**H**$_2$-) and 1.36 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$); ^{13}C-NMR ($CDCl_3$) δ (ppm): 166.8 (-**C**OO-), 130.7, 130.6, 125.9, 125.4, 125.3 and 114.8 (aromatic carbons), 134.6 and 115.0 (olefinic carbons), 60.8 (-O**C**H$_2$-) and 14.3 (-**C**H$_3$).

The FT-IR, ^{1}H and ^{13}C-NMR of **S12** are shown in Figures A.1-A.3. (see Appendix A)

Ethyl 2-methoxycinnamate (**S13**): Pale yellow liquid (74 %), R_f 0.60 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 8.03 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.54 (*d*, *J* = 7.62 Hz, 1H, Ar-**H**), 7.38 (*t*, *J* = 8.20 Hz, 1H, Ar-**H**), 7.02-6.94 (Ar-**H**, 2H), 6.56 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.30 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-), 3.93 (*s*, 3H, -OC**H**$_3$) and 1.37 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 3-methoxycinnamate (**S14**): Pale yellow liquid (90 %), R_f 0.57 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.69 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.34 (*t*, *J* = 7.03 Hz, 1H, Ar-**H**), 7.16 (*d*, *J* = 7.62 Hz, 1H, Ar-**H**), 7.08 (*s*, 1H, Ar-**H**), 6.97 (*d*, *J* = 8.20 Hz, 1H, Ar-**H**), 6.46 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.30 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-), 3.87 (*s*, 3H, -OC**H**$_3$) and 1.38 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 4-methoxycinnamate (**S15**): Pale yellow liquid (82 %), R_f 0.65 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.68 (*d*, *J* = 16.42 Hz, 1H, Ar-C**H**=), 7.52 (*d*, *J* = 8.80 Hz, 2H, Ar-**H**), 6.94 (*d*, *J* = 8.80 Hz, 2H, Ar-**H**), 6.35 (*d*, *J* = 15.83 Hz, 1H, =C**H**-COOR), 4.29 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-), 3.88 (*s*, 3H, -OC**H**$_3$) and 1.37 (*t*, *J* = 7.04 Hz, 3H, -C**H**$_3$).

Ethyl 4-butyloxycinnamate (**S16**): Pale yellow liquid (41 %), R_f 0.68 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.67 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.50 (*d*, *J* = 8.79 Hz, 2H, Ar-**H**), 6.92 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 6.34 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 4.29 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-), 4.02 (*t*, *J* = 6.44 Hz, 2H, -OC**H**$_2$-), 1.81 (*quin*, *J* = 7.03 Hz, 2H, -C**H**$_2$-), 1.48-1.58 (*m*, 2H, -C**H**$_2$-), 1.37 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$) and 1.01 (*t*, *J* = 7.62 Hz, 3H, -C**H**$_3$).

Ethyl 4-hexyloxycinnamate (**S17**): Pale yellow liquid (44 %), R_f 0.63 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.67 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.50 (*d*, *J* = 8.79 Hz, 2H, Ar-**H**), 6.92 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 6.34 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 4.29 (*q*, *J* = 7.03 Hz, 2H, -OC**H$_2$**-), 4.01 (*t*, *J* = 6.44 Hz, 2H, -OC**H$_2$**-), 1.82 (*quin*, *J* = 7.03 Hz, 2H, -C**H$_2$**-), 1.50-1.32 (*m*, 9H, 3x-C**H$_2$**-, -C**H$_3$**) and 0.94 (*t*, *J* = 7.03 Hz, 3H, -C**H$_3$**).

Ethyl 4-octyloxycinnamate (**S18**): Yellow viscous oil (50 %), R_f 0.73 (hexane/ethyl acetate 50%); IR (neat, cm^{-1}): 3015, 2929, 2859, 1707, 1633, 1602, 1513, 1466, 1302, 1248 and 1166; ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.67 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.50 (*d*, *J* = 8.79 Hz, 2H, Ar-**H**), 6.92 (*d*, *J* = 8.79 Hz, 2H, Ar-**H**), 6.33 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 4.28 (*q*, *J* = 7.03 Hz, 2H, -OC**H$_2$**-), 4.01 (*t*, *J* = 6.44 Hz, 2H, -OC**H$_2$**-), 1.82 (*qui*, *J* = 7.03 Hz, 2H, -C**H$_2$**-), 1.50-1.32 (*m*, 13H, 5x -C**H$_2$**-, -C**H$_3$**) and 0.92 (*t*, *J* = 6.44 Hz, 3H, -C**H$_3$**); ^{13}C-NMR ($CDCl_3$) δ (ppm): 167.5 (-**C**OO-), 161.0, 129.7 (2x1C), 126.9 and 114.8 (2x1C) (aromatic carbons), 144.4 and 115.5 (olefinic carbons), 68.2, 60.4 (-O**C**H$_2$-), 31.8, 29.4, 29.3, 29.2, 26.0, 22.7 (-**C**H$_2$-), 14.4 and 14.1 (-**C**H$_3$).

The FT-IR, ^{1}H and ^{13}C-NMR of **S18** are shown in Figures A.4-A.6. (see Appendix A)

Ethyl 4-dodecyloxycinnamate (**S19**): Yellow viscous oil (35 %), R_f 0.70 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.67 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.50 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 6.92 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 6.33 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 4.29 (*q*, *J* = 7.03 Hz, 2H, -OC**H$_2$**-), 4.01 (*t*, *J* = 6.44 Hz, 2H, -OC**H$_2$**-), 1.82 (*quin*, *J* = 7.03 Hz, 2H, -C**H$_2$**-), 1.52-1.30 (*m*, 21H, 9x-C**H$_2$**-, -C**H$_3$**) and 0.92 (*t*, *J* = 7.03 Hz, 3H, -C**H$_3$**).

Ethyl 4-benzyloxycinnamate (**S20**): White crystal (30 %), m.p. 58-60°C (diethyl ether) (lit.[23] 61-62°C), R_f 0.68 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.67 (*d*, *J* = 16.40 Hz, 1H, Ar-C**H**=), 7.51 (*d*, *J* = 8.79 Hz, 2H, Ar-**H**), 7.47-7.37 (*m*, 5H, Ar-**H**), 7.01 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 6.34 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 5.14 (*s*, 2H, -OC**H$_2$**-), 4.29 (*q*, *J* = 7.03 Hz, 2H, -OC**H$_2$**-) and 1.37 (*t*, *J* = 7.03 Hz, 3H, -C**H$_3$**).

Ethyl 4-phenoxycinnamate (**S21**): Pale yellow liquid (57 %), R_f 0.68 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.66 (*d*, *J* = 16.40 Hz, 1H,

Ar-C**H**=), 7.42-7.05 (*m*, 9H, Ar-**H**), 6.41 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.29 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-) and 1.36 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 4-butyloxy-3-methoxycinnamate (**S22**): Brown solid (81 %), m.p. 66-68°C (diethyl ether), R_f 0.63 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.66 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.12 (*s*, 1H, Ar-**H**), 7.09 (*d*, *J* = 7.03 Hz, 1H, Ar-**H**), 6.89 (*d*, *J* = 8.20 Hz, 1H, Ar-**H**), 6.34 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 4.29 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-), 4.08 (*t*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-), 3.92 (*s*, 3H, -OC**H**$_3$), 1.87 (*quin*, *J* = 7.62 Hz, 2H, -C**H**$_2$-), 1.53(*m*, 2H, -C**H**$_2$-) 1.37 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$) and 1.01 (*t*, *J* = 7.62 Hz, 3H, -C**H**$_3$).

Ethyl 4-hexyloxy-3-methoxycinnamate (**S23**): Pale yellow liquid (81 %), R_f 0.63 (hexane/ethyl acetate 50%); IR (neat, cm^{-1}): 3062, 2929, 2859, 1703, 1633, 1594, 1509, 1466, 1420, 1302, 1256 and 1166; ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.63 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.09 (*s*, 1H, Ar-**H**), 7.06 (*d*, *J* = 8.20 Hz, 1H, Ar-**H**), 6.86 (*d*, *J* = 8.20 Hz, 1H, Ar-**H**), 6.31 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 4.26 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-), 4.04 (*t*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-), 3.90 (*s*, 3H, -OC**H**$_3$), 1.86 (*quin*, *J* = 7.62 Hz, 2H, -C**H**$_2$-), 1.48-1.25 (*m*, 9H, 3x-C**H**$_2$-, -C**H**$_3$) and 0.89 (*t*, *J* = 6.44 Hz, 3H, -C**H**$_3$); ^{13}C-NMR ($CDCl_3$) δ (ppm): 167.3 (-**C**OO-), 150.7, 144.6, 127.2, 122.6, 112.2 and 109.9 (aromatic carbons), 149.4 and 115.7 (olefinic carbons), 56.0 (-O**C**H$_3$), 69.0, 60.4 (-O**C**H$_2$-), 31.6, 29.0, 25.6, 22.6 (-**C**H$_2$-), 14.4 and 14.1 (-**C**H$_3$).

The FT-IR, ^{1}H and ^{13}C-NMR of **S23** are shown in Figures A.7-A.9. (see Appendix A)

Ethyl 4-octyloxy-3-methoxycinnamate (**S24**): Yellow liquid (48 %), R_f 0.69 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.65 (*d*, *J* = 16.40 Hz, 1H, Ar-C**H**=), 7.11 (*s*, 1H, Ar-**H**), 7.08 (*d*, *J* = 8.20 Hz, 1H, Ar-**H**), 6.88 (*d*, *J* = 8.20 Hz, 1H, Ar-**H**), 6.33 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.31-3.96 (*m*, 2H, -OC**H**$_2$-), 3.92 (*s*, 3H, -OC**H**$_3$), 1.93-1.30 (*m*, 15H, 6x-C**H**$_2$-, -C**H**$_3$) and 0.91 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 4-dodecyloxy-3-methoxycinnamate (**S25**): Yellow needle crystal (50 %), m.p. 44-46°C (diethyl ether), R_f 0.68 (hexane/ethyl acetate 50%); IR (KBr, cm^{-1}): 2921, 2848, 1711, 1633, 1594, 1509, 1466, 1415, 1310, 1260, 1166 and 1143; ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.66 (*d*, *J* = 16.38 Hz, 1H, Ar-C**H**=), 7.12 (*s*, 1H, Ar-**H**), 7.09 (*d*, *J* = 6.40 Hz, 1H, Ar-**H**), 6.89 (*d*, *J* = 7.80 Hz, 1H, Ar-**H**), 6.34 (*d*, *J* = 15.60 Hz, 1H, =C**H**-COOR), 4.29 (*q*, *J* = 7.02 Hz, 2H, -OC**H**$_2$-), 4.07 (*t*, *J* = 7.02 Hz, 2H,

-OC**H**$_2$-), 3.93 (*s*, 3H, -OC**H**$_3$), 1.90-1.28 (*m*, 23H, 10x-C**H**$_2$-, -C**H**$_3$) and 0.91 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$); ^{13}C-NMR ($CDCl_3$) δ (ppm): 167.4 (-**C**OO-), 150.7, 144.7, 127.2, 122.6, 112.2 and 109.9 (aromatic carbons), 149.4 and 115.7 (olefinic carbons), 56.0 (-O**C**H$_3$), 69.0, 60.4 (-OCH$_2$-), 32.0, 29.7 (2x1C), 29.7, 29.6, 29.6, 29.4, 29.0, 25.9, 22.7 (-**C**H$_2$-), 14.4 and 14.2 (-**C**H$_3$).

The FT-IR, ^{1}H and ^{13}C-NMR of **S25** are shown in Figures A.10-A.12. (see Appendix A)

Ethyl 4-benzyloxy-3-methoxycinnamate (**S26**): Yellow solid (73 %), m.p. 61-62°C (diethyl ether) (lit.[24] 64°C), R_f 0.70 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.61 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.44-7.31 (*m*, 5H, Ar-**H**), 7.07 (*s*, 1H, Ar-**H**), 7.03 (*d*, *J* = 7.62 Hz, 1H, Ar-**H**), 6.87 (*d*, *J* = 8.20 Hz, 1H, Ar-**H**), 6.30 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 5.20 (*s*, 2H, -OC**H**$_2$-), 4.26 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-), 3.90 (*s*, 3H, -OC**H**$_3$) and 1.34 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 2,3-dimethoxycinnamate (**S27**): Pale yellow liquid (67 %), R_f 0.70 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 8.00 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.16 (*d*, *J* = 7.03 Hz, 1H, Ar-**H**), 7.06 (*t*, *J* = 8.20 Hz, 1H, Ar-**H**), 6.94 (*d*, *J* = 7.03 Hz, 1H, Ar-**H**), 6.49 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 4.27 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-), 3.88 (*s*, 3H, -OC**H**$_3$), 3.87 (*s*, 3H, -OC**H**$_3$) and 1.35 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 2,4-dimethoxycinnamate (**S28**): Pale yellow liquid (89 %), R_f 0.55 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.94 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.47 (*d*, *J* = 8.20 Hz, 1H, Ar-**H**), 6.53 (*d*, *J* = 8.79 Hz, 1H, Ar-**H**), 6.49 (*s*, 1H, Ar-**H**), 6.47 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.28 (*q*, *J* = 7.62 Hz, 2H, -OC**H**$_2$-), 3.90 (*s*, 3H, -OC**H**$_3$), 3.87 (*s*, 3H, -OC**H**$_3$) and 1.36 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 2,5-dimethoxycinnamate (**S29**): Pale yellow liquid (82 %), R_f 0.75 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 8.00 (*d*, *J* = 16.40 Hz, 1H, Ar-C**H**=), 7.08 (*s*, 1H, Ar-**H**), 6.94 (*d*, *J* = 8.79 Hz, 1H, Ar-**H**), 6.88 (*d*, *J* = 8.20 Hz, 1H, Ar-**H**), 6.53 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.30 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-), 3.88 (*s*, 3H, -OC**H**$_3$), 3.82 (*s*, 3H, -OC**H**$_3$) and 1.37 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 3,4-dimethoxycinnamate (**S30**): White solid (89 %), m.p. 59-61°C (diethyl ether) (lit.[25] 55-56°C), R_f 0.60 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$)

δ (ppm): 7.66 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.14 (*d*, *J* = 7.62 Hz, 1H, Ar-**H**), 7.09 (*s*, 1H, Ar-**H**), 6.90 (*d*, *J* = 8.20 Hz, 1H, Ar-**H**), 6.35 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 4.30 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-), 3.94 (*s*, 6H, 2x-OC**H**$_3$) and 1.37 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 3,5-dimethoxycinnamate (**S31**): Pale yellow needle crystal (83 %), m.p. 42-43°C (diethyl ether) (lit.[26] 45-46°C), R_f 0.69 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.63 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 6.69 (*s*, 2H, Ar-**H**), 6.51 (*s*, 1H, Ar-**H**), 6.43 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 4.28 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-), 3.83 (*s*, 6H, -OC**H**$_3$) and 1.37 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 3,4,5-trimethoxycinnamate (**S32**): Yellow solid (85 %), m.p. 66-68°C (diethyl ether), R_f 0.58 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.63 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.78 (*s*, 2H, Ar-**H**), 6.38 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.30 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-), 3.92 (*s*, 9H, -OC**H**$_3$) and 1.37 (*t*, *J* = 7.04 Hz, 3H, -C**H**$_3$).

Ethyl 4-nitrocinnamate (**S36**): Brown needle crystal (82 %), m.p. 136-137°C (diethyl ether), R_f 0.68 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 8.26 (*d*, *J* = 8.79 Hz, 1H, Ar-**H**), 7.71 (*d*, *J* = 16.40 Hz, 1H, Ar-C**H**=), 7.68 (*d*, *J* = 8.78 Hz, 2H, Ar-**H**), 6.56 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.30 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-) and 1.36 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 2-chloro-5-nitrocinnamate (**S37**): Brown needle crystal (80 %), m.p. 114-116°C (diethyl ether), R_f 0.70 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 8.49 (*s*, 1H, Ar-**H**), 8.17 (*d*, *J* = 8.79 Hz, 1H, Ar-**H**), 8.05 (*d*, *J* = 16.40 Hz, 1H, Ar-C**H**=), 7.62 (*d*, *J* = 8.79 Hz, 1H, Ar-**H**), 6.59 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 4.31 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-) and 1.37 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 4-chloro-3-nitrocinnamate (**S38**): Brown needle crystal (71 %), m.p. 128-130°C (ethanol) (lit.[27] 130.5-131.5°C), R_f 0.68 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 8.02 (*s*, 1H, Ar-**H**), 7.66-7.57 (*m*, 2H, Ar-**H**), 7.61 (*d*, *J* = 16.40 Hz, 1H, Ar-C**H**=), 6.51 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.29 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-) and 1.35 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 5-chloro-2-nitrocinnamate (**S39**): Brown solid (87 %), m.p. 58-60°C (diethyl ether) (lit.[28] 61.0-62.5°C), R_f 0.65 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 8.08 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 8.04 (*d*, *J* = 8.79 Hz, 1H, Ar-

H), 7.60 (*s*, 1H, Ar-**H**), 7.51 (*d*, *J* = 8.79 Hz, 1H, Ar-**H**), 6.37 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 4.30 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-) and 1.35 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$).

Ethyl 4-methylcinnamate (**S40**): Yellow liquid (65 %), R_f 0.73 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.70 (*d*, *J* = 16.40 Hz, 1H, Ar-C**H**=), 7.46 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 7.23 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 6.43 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 4.29 (*q*, *J* = 7.62 Hz, 2H, -OC**H**$_2$-), 2.41 (*s*, 3H, -C**H**$_3$) and 1.37 (*t*, *J* = 7.62 Hz, 3H, -C**H**$_3$).

Ethyl 4-isopropylcinnamate (**S41**): Yellow liquid (48 %), R_f 0.70 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.72 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.50 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 7.28 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 6.44 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 4.30 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-), 2.96 (*m*, 1H, -C**H**-), 1.37 (*t*, *J* = 7.03 Hz, 3H, -C**H**$_3$), 1.30 (*s*, 3H, -C**H**$_3$) and 1.28 (*s*, 3H, -C**H**$_3$).

Ethyl 4-tertbutylcinnamate (**S42**): Yellow liquid (61 %), R_f 0.65 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.71 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.51 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 7.44 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 6.44 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.30 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-) and 1.39-1.36 (*m*, 12H, -C**H**$_3$).

Ethyl 4-trifluoromethylcinnamate (**S43**): Yellow liquid (86 %), R_f 0.74 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.73 (*d*, *J* = 16.42 Hz, 1H, Ar-C**H**=), 7.69 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 7.66 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 6.55 (*d*, *J* = 15.83 Hz, 1H, =C**H**-COOR), 4.32 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-) and 1.39 (*t*, *J* = 7.04 Hz, 3H, -C**H**$_3$).

Ethyl 3-cyanocinnamate (**S44**): Yellow solid (72 %), m.p. 66-67°C (diethyl ether) (lit.[29] 69-70.5°C), R_f 0.63 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.83 (*s*, 1H, Ar-**H**), 7.78 (*d*, *J* = 7.62 Hz, 1H, Ar-**H**), 7.70 (*d*, *J* = 7.62 Hz, 1H, Ar-**H**), 7.68 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.55 (*d*, *J* = 7.62 Hz, 2H, Ar-**H**), 6.52 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.32 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-) and 1.38 (*t*, *J* = 7.04 Hz, 3H, -C**H**$_3$).

Ethyl 4-cyanocinnamate (**S45**): White crystal (87 %), m.p. 67-68°C (diethyl ether) (lit.[30] 69.5°C), R_f 0.71 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.72 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 7.70 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.65 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 6.55 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.32 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-) and 1.38 (*t*, *J* = 7.62 Hz, 3H, -C**H**$_3$).

Ethyl 3-(1-naphthalene)-propionate (**S46**): Yellow liquid (69 %), R_f 0.64 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 8.53 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 8.21 (*d*, *J* = 8.79 Hz, 1H, Ar-**H**), 7.89 (*t*, *J* = 7.03 Hz, 2H, Ar-**H**), 7.76 (*d*, *J* = 7.62 Hz, 1H, Ar-**H**), 7.60-7.47 (*m*, 3H, Ar-**H**), 6.53 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 4.32 (*q*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-) and 1.38 (*t*, *J* = 7.62 Hz, 3H, -C**H**$_3$).

Methyl cinnamate (**S47**): Yellow liquid (79 %), R_f 0.59 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.70 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.54-7.39 (*m*, Ar-**H**, 5H), 6.45 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR) and 3.81 (*s*, 3H, -OC**H**$_3$).

Methyl 2-chlorocinnamate (**S48**): Yellow liquid (74 %), R_f 0.40 (hexane/ethyl acetate 80%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 8.13 (*d*, *J* = 16.42 Hz, 1H, Ar-C**H**=), 7.65 (*d*, *J* = 7.62 Hz, 1H, Ar-**H**), 7.45 (*d*, *J* = 7.62 Hz, 1H, Ar-**H**), 7.35-7.31 (*m*, Ar-**H**, 2H), 6.47 (*d*, *J* = 15.83 Hz, 1H, =C**H**-COOR) and 3.86 (*s*, 3H, -OC**H**$_3$).

Methyl 4-methylcinnamate (**S49**): White crystal (75 %), m.p. 50-52°C (diethyl ether) (lit.[31] 58°C), R_f 0.60 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.70 (*d*, *J* = 16.40 Hz, 1H, Ar-C**H**=), 7.46 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 7.23 (*d*, *J* = 8.20 Hz, 2H, Ar-**H**), 6.43 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 3.85 (*s*, 3H, -OC**H**$_3$) and 2.41 (*s*, 3H, -C**H**$_3$).

Methyl 4-methoxycinnamate (**S50**): White crystal (75 %), m.p. 51-52°C (diethyl ether) (lit.[31] 55-56°C), R_f 0.60 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.66 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.48 (*d*, *J* = 8.79 Hz, 2H, Ar-**H**), 6.91 (*d*, *J* = 8.79 Hz, 2H, Ar-**H**), 6.32 (*d*, *J* = 15.82 Hz, 1H, =C**H**-COOR), 3.84 (*s*, 3H, -OC**H**$_3$) and 3.80 (*s*, 3H, -OC**H**$_3$).

Butyl cinnamate (**S51**): Yellow liquid (73 %), R_f 0.61 (hexane/ethyl acetate 50%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.69 (*d*, *J* = 15.82 Hz, 1H, Ar-C**H**=), 7.55-7.39 (*m*, Ar-**H**, 5H), 6.45 (*d*, *J* = 16.40 Hz, 1H, =C**H**-COOR), 4.21 (*t*, *J* = 7.03 Hz, 2H, -OC**H**$_2$-), 1.70 (*quin*, *J* = 7.62 Hz, 2H, -C**H**$_2$-), 1.44 (*m*, 2H, -C**H**$_2$-) and 0.97 (*t*, *J* = 7.62 Hz, 3H, -C**H**$_3$).

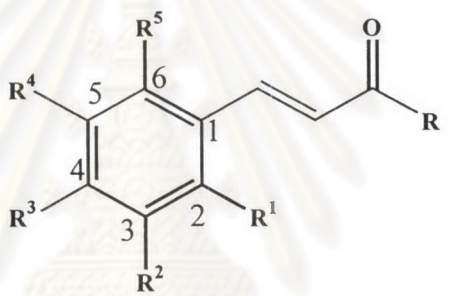
Butyl 2-chlorocinnamate (**S52**): Yellow liquid (70 %), R_f 0.48 (hexane/ethyl acetate 80%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 8.13 (*d*, *J* = 16.42 Hz, 1H, Ar-C**H**=), 7.66 (*d*, *J* = 7.62 Hz, 1H, Ar-**H**), 7.45 (*d*, *J* = 7.62 Hz, 1H, Ar-**H**), 7.36-7.31 (*m*, Ar-**H**, 5H), 6.47 (*d*, *J* = 16.42 Hz, 1H, =C**H**-COOR), 4.26 (*t*, *J* = 7.04 Hz, 2H, -OC**H**$_2$-), 1.74 (*quin*, *J* = 7.62 Hz, 2H, -C**H**$_2$-), 1.48 (*m*, 2H, -C**H**$_2$-) and 1.01 (*t*, *J* = 7.62 Hz, 3H, -C**H**$_3$).

2.3.2 Synthesis of *trans*-Cinnamamides

General Procedure[32]

Triphenylphosphine 2 eq (6 mmol, 1.57 g) in CH_2Cl_2 3 mL was added to a mixture of selected cinnamic acid 1 eq (3 mmol) and trichloroacetamide 2 eq (6 mmol) in CH_2Cl_2 3 mL. The mixture was stirred under reflux for 1 hour. A mixture of selected amine 1 eq (3 mmol) and 4-picoline 3 eq (9 mmol) was added to the above reaction mixture. The reaction was continued refluxing for another hour. When the reaction was completed (checking by TLC), the organic layer was extracted with 10% HCl and saturated aqueous $NaHCO_3$, respectively, dried over Na_2SO_4 and evaporated *in vacuo*. The mixture was separated with column chromatography on silica gel.

Two cinnamamides were synthesized and the structures of six cinnamamides studied are displayed as shown in Figure 2.2.



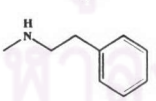
Cpds	R	R^1	R^2	R^3	R^4	R^5
M01	NHC_2H_5	**Cl**	H	H	H	H
M02	NHC_2H_5	H	H	**CH_3**	H	H
M03**	$N(C_2H_5)_2$	**Cl**	H	H	H	H
M04*	NHC_4H_9	H	H	**CH_3**	H	H
M05**		H	**OCH_2O**		H	H
M06**		H	**OCH_2O**		H	H

Figure 2.2 Structures of synthesized substituted cinnamamides

*M04 was kindly donated from Ms. Sujittra Deesamer.[17]

**These compounds were kindly provided from Ms. Skaydaw Chaysripongkul.[32]

(N-Ethyl)-2-chlorocinnamamide (**M01**): Pale yellow liquid (14 %), R_f 0.33 (hexane/ethyl acetate 70%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 8.13 (*d*, *J* = 15.83 Hz, 1H, Ar-C**H**=), 7.65 (*d*, *J* = 7.04 Hz, 1H, Ar-**H**), 7.44 (*d*, *J* = 8.21 Hz, 1H, Ar-**H**), 7.36-7.31

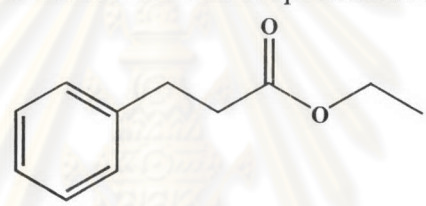
(*m*, Ar-**H**, 2H), 6.47 (*d*, *J* = 15.83 Hz, 1H, =C**H**-COOR), 3.86 (*s br*, 2H, -NHC**H**$_2$-) and 1.28 (*s br*, 3H, -C**H**$_3$).

(N-Ethyl)-4-methylcinnamamide (**M02**): Pale yellow liquid (13 %), R_f 0.33 (hexane/ethyl acetate 70%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.71 (*d*, *J* = 15.83 Hz, 1H, Ar-C**H**=), 7.46 (*d*, *J* = 7.62 Hz, 2H, Ar-**H**), 7.23 (*d*, *J* = 7.62 Hz, 2H, Ar-**H**), 6.43 (*d*, *J* = 15.83 Hz, 1H, =C**H**-COOR), 3.84 (*s br*, 2H, -NHC**H**$_2$-), 2.41 (*s*, 3H, -OC**H**$_3$) and 1.29 (*s br*, 3H, -C**H**$_3$).

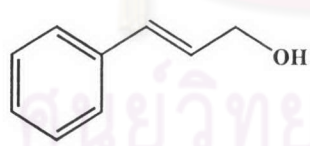
2.3.3 Synthesis of Miscellaneous Cinnamic Acid Derivatives

Hydrogenation of Ethyl Cinnamate[33]

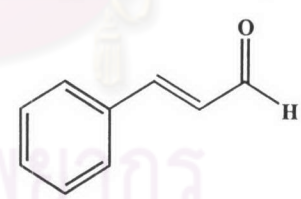
Ethyl cinnamate (5 mmol) in 10 mL of ethyl acetate was hydrogenated over 0.071 g of 10% palladium on charcoal at *ca.* 1 atm hydrogen pressure on a shaker at room temperature. Hydrogen uptake was completed after *ca.* 4 hours. The catalyst was removed by filtration and the solvent was evaporated *in vacuo.*



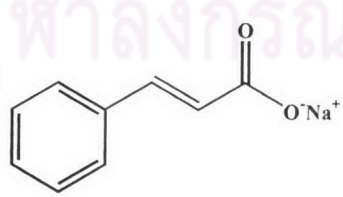
Ethyl 3-phenylpropionate (**X03**): Yellow liquid (55 %), R_f 0.53 (hexane/ethyl acetate 80%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.34-7.24 (*m*, 5H, Ar-**H**), 4.17 (*q*, 2H, -OC**H**$_2$-), 2.99 (*t*, *J* = 7.02 Hz, 2H, Ar-C**H**$_2$-), 2.66 (*t*, *J* = 7.80 Hz, 2H, -C**H**$_2$-) and 1.27 (*t*, *J* = 7.02 Hz, 3H, -C**H**$_3$).



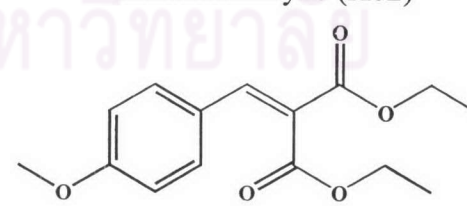
cinnamyl alcohol (**X01**)



cinnamaldehyde (**X02**)



sodium cinnamate (**X04***)



diethyl-4′-methoxybenzalmalonate (**X05****)

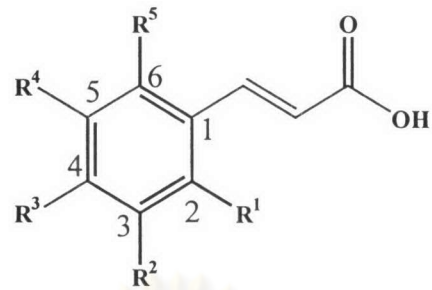
Note: **X01** and **X02** are commercially available.

***X04** was kindly donated from Ms. Sujittra Deesamer.[17]

****X05** was kindly gifted from Ms. Thitinun Monhaphol.[34]

2.3.4 Synthesis of Substituted *trans*-Cinnamic Acids

The structures of five cinnamic acid derivatives are displayed as shown in Figure 2.3.



Cpds	R^1	R^2	R^3	R^4	R^5
A00*	H	H	H	H	H
A01*	**Cl**	H	H	H	H
A02*	H	H	**CH_3**	H	H
A03*	H	**OCH_2O**		H	H
A04*	H	**NO_2**	H	H	H

Figure 2.3 Structures of substituted cinnamic acids

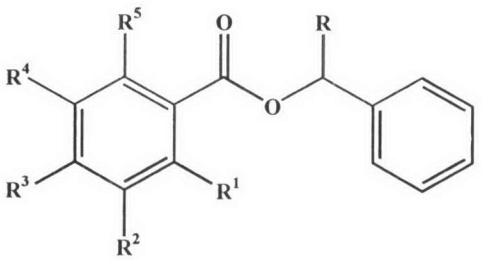
*These compounds were kindly donated from Ms. Sujittra Deesamer.[17]

2.4 Synthesis of Substituted Benzyl Benzoate Derivatives

General Procedure[32]

Triphenylphosphine 2 eq (6 mmol, 1.57 g) in CH_2Cl_2 3 mL was added to a mixture of selected benzoic acid 1 eq (3 mmol) and trichloroacetamide 2 eq (6 mmol) in CH_2Cl_2 3 mL. The mixture was stirred under reflux for 1 hour. A mixture of 1-phenylethanol 1 eq (3 mmol) and 4-picoline 3 eq (9 mmol) was added to the above reaction mixture. The reaction was continued refluxing for another hour. When the reaction was completed (following by TLC), the organic layer was extracted with 10% HCl and saturated aqueous $NaHCO_3$ respectively, dried over Na_2SO_4 and evaporated *in vacuo*. The mixture was separated with column chromatography on silica gel.

Three benzyl benzoate derivatives were synthesized and the structures of four benzyl benzoate derivatives studied are displayed as shown in Figure 2.4.



Cpds	R	R^1	R^2	R^3	R^4	R^5
B00*	H	H	H	H	H	H
B01	H	**Cl**	H	H	H	H
B02	**CH_3**	H	H	H	H	H
B03	**CH_3**	**Cl**	H	H	H	H

Figure 2.4 Structures of substituted benzyl benzoate

***B00** was kindly donated from Ms. Skaydaw Chaysripongkul.[32]

Benzyl 2-chlorobenzoate (**B01**): Pale pink liquid (30 %), R_f 0.58 (hexane/ethyl acetate 70%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.86-7.26 (*m*, 9H, Ar-**H**) and 5.38 (*s*, 2H, -OC**H$_2$**-).

1-Phenylethyl benzoate (**B02**): Pale yellow liquid (84 %), R_f 0.58 (hexane/ethyl acetate 70%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 8.10-7.26 (*m*, 10H, Ar-**H**), 6.14 (*q*, *J* = 6.44 Hz, 1H, -OC**H**-) and 1.68 (*d*, 3H, -C**H$_3$**).

1-Phenylethyl 2-chlorobenzoate (**B03**): Pale yellow liquid (73 %), R_f 0.57 (hexane/ethyl acetate 70%); ^{1}H-NMR ($CDCl_3$) δ (ppm): 7.88-7.33 (*m*, 9H, Ar-**H**), 6.18 (*q*, *J* = 6.45 Hz, 1H, -OC**H**-) and 1.73 (*d*, 3H, -C**H$_3$**).

2.5 Bioassay Experiments

2.5.1 Insecticidal Activity (Contact toxicity: topical application)

Common cutworm (*S. litura*) obtained from Department of Agriculture, Ministry of Agriculture and cooperatives was used as an insect model in this research.

General Procedure[5]

The samples were prepared by dissolving $4x10^{-7}$ mol of tested compound in 1 mL of a proper solvent. Common cutworms, *Spodoptera litura,* were reared on an artificial diet in a controlled environment. Ten of third instar larvae were placed in the petri dish and 10 μL of the tested compound was dropped with a micropipette. The artificial diets were contained in the petri dish and kept at 25°C for 24 hours (4 replications). The control solution was prepared by using only a proper solvent.

After 24 hours, the died cutworms were counted and converted to percentage of died larvae (% mortality) of *S. litura*. Finally, the LD_{50} was calculated by probit analysis program.

2.5.2 Antifeedant Activity (Choice leaf disk bioassay)[35]

Leaf-disks, 1.9 cm diameter, were prepared with a cork borer from fresh sweet potato (*Ipomoea batatas*) leaves that had been cultivated without agrochemicals.

Two disks were treated with a specific amount of plant extracts or tested compounds dissolved in a proper solvent. Other two disks were prepared using the same solvent as the control. The four disks were set in alternating positions in the same petri dish. After complete removal of the solvent, 10 larvae (third instars) were released into the dish. The dishes were then kept in an insect rearing room at 25°C in the dark for 18 hours. Partially consumed leaf-disks were taped onto photocopier paper for monotone data conversion. The monotone data was photocopied, determined to contain no errors, and then converted to digital data files using a digital scanner. Digital data analyses were performed on a PC computer using the public-domain Scion image program (developed by the U.S. National Institutes of Health and available from the Internet by anonymous FTP from www.scioncorp.com). For each experiment, the data file of an intact disk was measured and compared with that of treated disk. For evaluation of the antifeedant activity of the extracts and tested compounds, three citerias: antifeedant index (AFI), feeding inhibitory (FI) and control

disk consumption (CDC) derived from the calculation according to the following formula were considered.

$$\text{Antifeedant Index (AFI)} = \frac{\text{\% treated disks consumed}}{\text{(\% treated disks consumed + \% control disks consumed)}} \times 100$$

$$\text{Feeding Inhibitory (FI)} = 100 - (\text{AFI} \times 2)$$

$$\text{Control Disk Comsumption (CDC)} = \frac{\text{control disk (pixl) - residue control disk (pixl)}}{\text{control disk (pixl)}} \times 100$$

2.6 Quantitative Structure-Activity Relationship (QSAR) Experiments

Structural Optimization

The three dimensional structures of all cinnamic acid derivatives, except compounds **X04** and **X05**, were built using a molecular modeling software and were subsequently subjected to geometry optimizations. The Hartree Fock method with 3-21G basis set, which generally gives a reasonable structure, was chosen for the geometry optimizations. All the calculations were performed using the Gaussian 98 program.[36]

Calculations of Properties

There are many physicochemical properties available for QSAR study. In this work, the following properties were calculated.

A. Hydrophobicity property: log P
B. Polarizability property: molar refractivity
C. Electronic properties: atomic charges, dipole moment, HOMO energy, LUMO energy, HOMO-LUMO gap
D. Steric properties: three connectivity indicies, *i.e.*, Chi1 (atoms), Chi2 (bond) and Chi3 (path) and three shape indicies, *i.e.*, Kappa 1, Kappa 2 and Kappa 3

Regression Analysis

A statistical multiple linear regression analysis was used to investigate a correlation between insecticidal activity and calculated physicochemical properties. The correlation was represented in a linear equation that best describes the dependency of insecticidal activity on physicochemical properties.

In order to justify a quality of correlation, a regression coefficient (r^2) was evaluated. It indicated how many percentage of the variation in the insecticidal activity could be explained by the physicochemical properties. Generally, a model with r^2 value higher than 0.81 for *in vitro* and 0.64 for *in vivo* biological data is accepted as a good model.[37] However the r^2 value does not give any information about a predictive ability of the model. Therefore, a cross-validated regression coefficient (q^2) was additionally calculated. An acceptable predictive model should have the q^2 value of more than 0.5.