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MEDICINAL CHEMISTRY RESEARCH

ORIGINAL RESEARCH

Synthesis and biological evaluation of some undecanone derivatives

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Abstract The total synthesis of Ardisinone E [**15**, 1-(2,4,6-trihydroxy phenyl)-11-(2-hydroxyphenyl)-undecan-1-one], a natural diarylundecanone, isolated from *Ardisia arborescens*, was accomplished along with 16 new diarylundecanone analogs (**18a–p**), by modified Wittig reaction. The structures of the compounds were confirmed by ^{1}H, ^{13}C and mass spectral data. Compound **15** showed potent cytotoxic activity with an ED_{50} of 4.19 µg/mL in brine shrimp lethality assay model. Compounds **18c**, **18e**, **18j**, **18k**, **18l**, and **18m** exhibited strong anti-oxidant activity with IC_{50} values of 18.75, 12.28, 18.35, 11.04, 12.05, and 11.32 µg/mL, respectively, in NBT free radical assay. Compounds **18e**, **18k**, and **18m** also showed significant 5-lipoxyganase enzyme inhibitory potential with IC_{50} values of 12.8, 15.23, and 15.23 µg/mL, respectively.

Keywords Ardisinone · Diarylundecanone · Ardisia arborescens · 5-lipoxyganase · Brine shrimp

Introduction

The plants of myristicaceae family are rich source of diarylalkanones which include diarylpropanoids (Isogai et al. 1973; Forrest et al. 1970; Forrest et al. 1974), diarylpentanoids (Knerachelin A & D) (Zahir et al. 1993), diarylnonanoids (Malabaricones A-D) (Purushothaman et al. 1977; Orabi et al. 1991; Cooray et al. 1987; Kumar et al. 1988; Zahir et al. 1993; Pinto et al. 1988) and diarylundecanoids (Lopes et al. 1982). *Myristica fragrans* and *Myristica malabarica* have been used in several Asian countries as the folk medicine (Jayaweera 1982) and as exotic spice in various Indian cuisines. The genus Ardisia of myristicaceae family includes more than 200 species. Plants of Ardisia are used in Chinese traditional medicine to cure pulmonary tuberculosis, hepatitis, chronic bronchitis and menstrual problems. Ardisinone E [**15**, 1-(2,4,6-trihydroxy phenyl)-11-(2-hydroxyphenyl)-undecan-1-one], a natural metabolite belonging to the class of compounds known as diarylundecanones, were isolated from *Ardisia arborescens* (Ying Zheng et al. 2004).

Natural occurrence of diarylundecanones is relatively less known and their biological effects have not been explored. Diarylnonanones possess wide range of biological activities and due to the close structural similarity of diarylundecanones with diarylnonanones the former are presumed to exhibit similar biological activities. This has prompted us to attempt the total synthesis of ardisinone E (**15**), a diarylundecanone derivative and evaluate its biological potential. In this process, we have also synthesized sixteen new diarylundecanones (**18a–p**) and screened them for their anti-oxidant, anti-inflammatory, and cytotoxicity potential.

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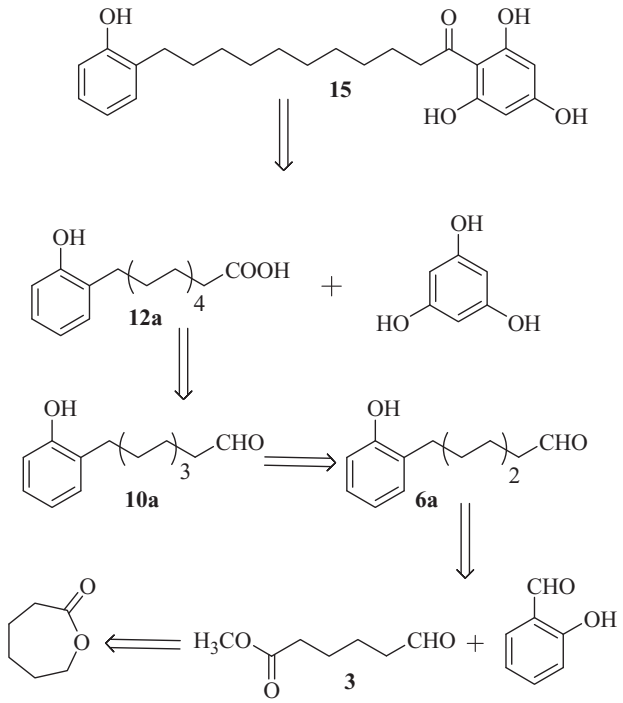
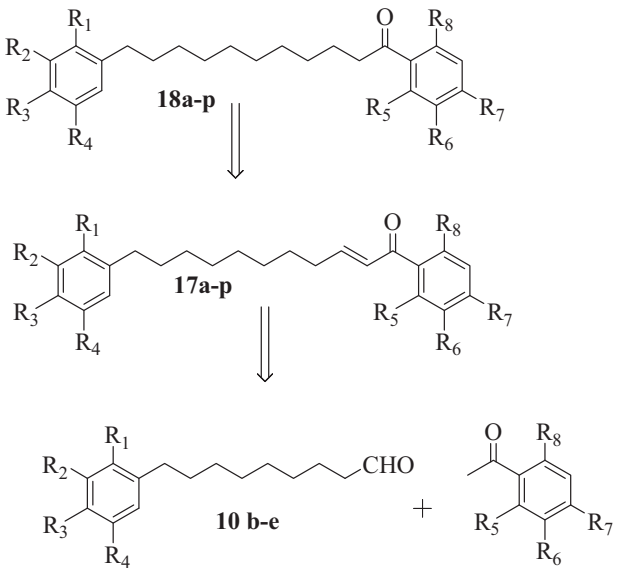


Scheme 1 Retrosynthetic analysis of ardisinone E



Scheme 2 Retrosynthetic analysis of undecanones (**18a–18p**)

Results and discussion

The total synthesis of ardisinone E was envisaged based on the retro synthetic analysis of diarylundecanone skeleton as depicted in Scheme 1. The disconnection approach revealed that phloroglucinol and 11(2-hydroxyphenyl)-undecanoic acid (**12a**) are the immediate precursors of ardisinone E. In addition, 9(2-hydroxyphenyl)-nonanal (**10a**) and 7(2-hydroxyphenyl)-heptanal (**6a**) are identified as other key intermediates in retro synthesis. Salicylaldehyde and methyl 6-al-hexanoate (**3**) are in turn the appropriate precursors for 7(2-hydroxyphenyl)-heptanal (**6a**). Finally ε-caprolactone can be the earliest precursor in the synthetic process of ardisinone E. Based on this retro synthetic analysis, the synthetic process as summarized in Schemes 3 and 4 was successfully adopted to prepare ardisinone E (**15**).

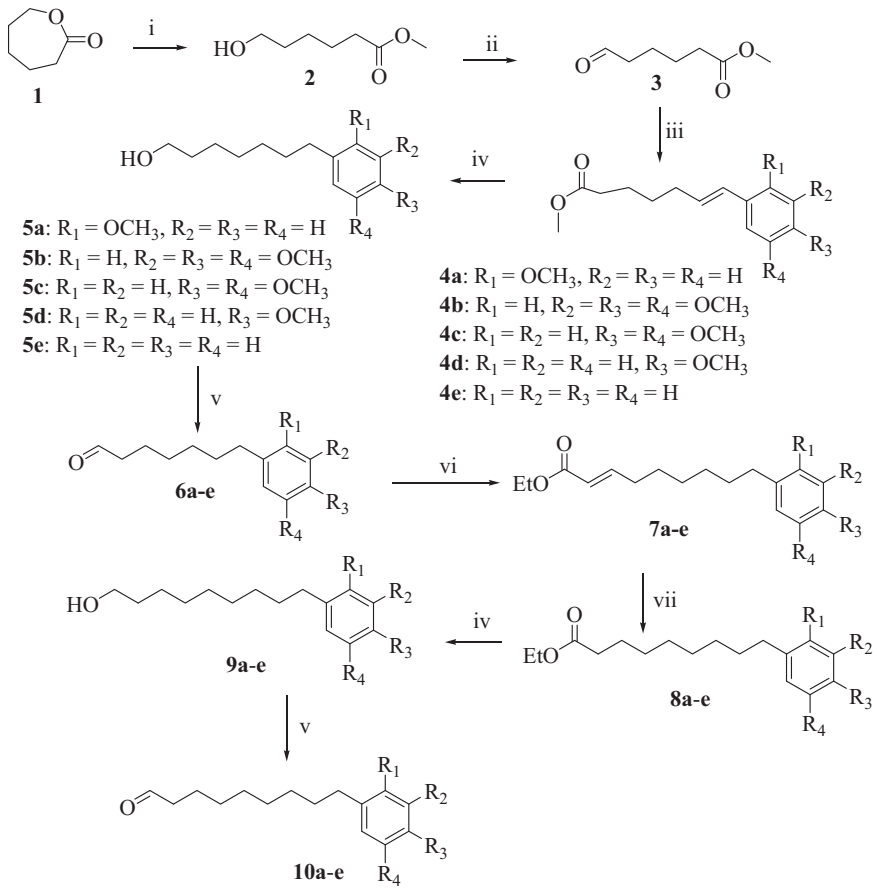
To explore the biological potential of compounds having diarylundecanone skeleton, the synthesis of several new diaryl undecanone derivatives, containing differently substituted aryl group in place of phloroglucinol and substituted phenyl group in place of 2-hydroxyphenyl group of ardisinone E was attempted, based on the retrosynthtic analysis adopted for ardisionone E.

However, the terminal reaction intermediates, viz. differently substituted arylundecanoic acid and phloroglucinol substitute did not undergo Friedel Craft′s acylation as expected probably because of the reduced electrophilicity of phloroglucinol variant. Hence, a modified retro synthetic approach as summarized in Scheme 2 was envisaged for compounds of general diarylundecanone skeleton and the synthesis of derivatives **18a–p** was accomplished by adopting the synthetic scheme depicted in Scheme 5.

The sequential disconnection Scheme 2 reveals that the enone intermediate (**17a–p**) could be the most advanced precursor for substituted diarylundecanone compounds. Further disconnection of this precursor between the α and β olefinic carbons of enone moiety leads to 9-(substituted phenyl)-nonanal (**10**) and commercially available substituted acetophenone as the advanced precursors. Further disconnection analysis revealed that aryl substituted 9-(2-hydroxyphenyl)-nonanal analogs (**10b–e**) can be produced from ε-caprolactone based on the same retrosynthetic strategy as described in Scheme 1.

Synthesis

Based on the disconnection approach summarized in Schemes 1 and 2, the key intermediate **10** of ardisinone and other diarylundecanones synthesis was prepared adopting the Scheme 3. The intermediate methyl 6-al-hexanoate (**3**) was obtained by cleaving the macrolactone ring of commercially available ε-caprolactone in presence of H_2SO_4 in methanol. The aldehyde **3** was then reacted with suitably substituted benzyltriphenylphosponium salts in presence of strong base to get methyl 7-(substituted phenyl)hept-6-en-1-oates (**4a–e**), which upon reduction with lithium aluminum hydride followed by mild oxidation of the reaction product with IBX yielded the aldehyde compounds 7-(substituted phenyl)heptan-1-al (**6a–e**, 65–72%). The aldehyde compounds **6a–e** were treated with



Scheme 3 Synthesis of main intermediate **10a–e**. Reagents and conditions: (i) H_2SO_4, methanol; (ii) Jones reagent, silicagel, dichloromethane; (iii) Sodium hydride, Wittig salt, THF; (iv) LAH, THF; (v) IBX, DMSO; (vi) Triphenylcarbethoxy-methylenephosphorane, THF; (vii) Pd/$CaCO_3$, ethyl acetate

triphenylcarbethoxymethylenephosphorane under modified Wittig reaction conditions to obtain compounds **7a–e** in good yields (65–74%). Triphenylcarbethoxymethylenephosphorane was prepared by adopting general methodology reported by Denney et.al. (Denney and Ross 1962).

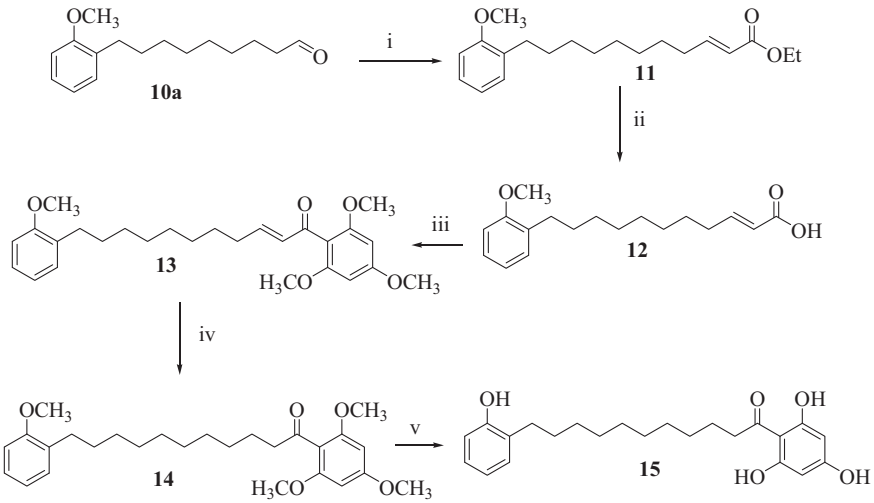
The compounds **7a–e** were subjected to catalytic reduction under hydrogen atmosphere with 5% Pd/$CaCO_3$ to obtain ethyl 9-(substituted phenyl)-nonanoates (**8a–e**) with yields in the range of 85–90%, which on reduction with LAH yielded 9-(substituted phenyl)nonan-ol compounds (**9a–e**) in 80–85% yield. The compounds **9a–e** were treated with IBX in dichloromethane to obtain 9-(substituted phenyl)nonan-al (**10a–e**) again in good yields (76–82%).

For the synthesis of ardisinone, the compound **10a** was treated with triphenylcarbethoxymethylenephosphorane under modified Wittig reaction conditions as depicted in Scheme 4, followed by base hydrolysis of the reaction product to give 11-(2-methoxy-phenyl) undec-2-en-1-oic acid (**12**) in 56% yield. The compound **12** was then treated with tri-*O*-methyl phloroglucinol in presence of aluminum chloride in dichloromethane at 0–5 °C to yield 11-(2-methoxy-phenyl)-1-(2,4,6-trimethoxy phenyl)undec-2-en-1-one (**13**, 65%). Compound **13** was subjected to catalytic reduction with Pd/$CaCO_3$ under hydrogen atmosphere to yield diarylundecanone **14** in 83% yield. Finally, the compound **14** on vigorous demethylation using pyridinium chloride afforded ardisinone E (**15**) in 35% yield.

For the synthesis of other diarylundecanones, the 9-(substituted phenyl)-nonan-al compounds **(10b–e)** were treated with substituted acetophenonephosphoranes **16a–d** via modified Wittig reaction to obtain 11-(substituted phenyl)-1-(substituted phenyl)-undec-2-ene-1-ones **(17a–p)** with yields in the range of 45–53%, which on catalytic hydrogenation with 5% Pd/$CaCO_3$ yielded the corresponding 11-(substituted phenyl)-1-(substituted phenyl)-undecan-1-one compounds **18a–p** in 75–87% yields as summarized Scheme 5.

Biological activities

All the compounds were tested to evaluate their potential as antioxidant and to inhibit 5-lipoxygenase enzyme and growth of brine shrimp. Ardisinone (**15**, 1-(2, 4, 6-trihydroxyphenyl)-11-(2-hydroxyphenyl)-undecane-1-one,) showed potent brine shrimp lethality with ED_{50} of 4.19 μg/mL. The other diarylundecanone compounds **18c**, **18e**, **18f**, **18j**, **18k**, **18l**, **18m**, **18o**, and **18p** showed moderate brine shrimp lethality with ED_{50} values of 50.51, 63.14, 85.64, 70.38,



Scheme 4 Synthesis of ardisinone E (**15**): Reagents and conditions: (i) Triphenylcarbethoxymethylenephosphorane, THF; (ii) NaOH, MeOH; (iii) $SOCl_2$, $AlCl_3$, dichloromethane, tri-*O*-methylphloroglucinol; (iv) $Pd/CaCO_3$, ethyl acetate; (v) Pyridinium chloride

44.67, 44.32, 60.09, 70.15, and 65.53 µg/mL respectively. Podophyllotoxin (ED_{50}: 1.92 µg/mL) was used as positive control.

Ardisinone E (**15**) showed moderate anti-oxidant activity (IC_{50}: 56.64 µg/mL) in in vitro NBT anti-oxidant model. The diarylundecanone analogs **18c**, **18e**, **18f**, **18j**, **18k**, **18l**, **18m**, and **18p** showed relatively superior anti-oxidant activity with IC_{50} values of 18.75, 12.28, 50.04, 18.35, 11.04, 12.05, 11.32, and 28.12 µg/mL, respectively. The positive control gallic acid showed an IC_{50} value of 2.34 µg/mL.

The anti-inflammatory potential of ardisinone E (**15**) and the diarylundecanone analogs **18a-p** were evaluated in 5-lipoxygenase enzyme inhibitory model. Compounds **18e**, **18k**, and **18m** strongly inhibited 5-lipoxygenase with IC_{50} values of 12.80, 15.23, and 15.23 µg/mL, respectively. The compounds **18c**, **18f**, **18j**, **18l**, **18o**, and **18p** showed moderate inhibitory activity with IC_{50} values of 62.10, 32.03, 35.54, 24.60, 43.35, and 53.51 µg/mL respectively. However, **15** showed inferior 5-lipoxygenase inhibition activity with $IC_{50} > 100$ µg/mL. In comparison, the positive control pure curcumin showed an IC_{50} value of 8.98 µg/mL.

Experimental

The ^1H NMR spectra were recorded on Bruker Avance AV 400 MHz NMR spectrometer and ^{13}C NMR spectra were recorded on Bruker Avance AV 100 MHz NMR spectrometer. Mass studies were performed on LC-MS system equipped with Agilent 1100 series LC/ MSD detector and 1100 series Agilent HPLC pump. Normal phase silica gel (ACME, 100–200 mesh) was used for column chromatography. Silica gel pre-coated plates (AlugramSil G/UV254) were used for thin layer chromatography. The plates were eluted with a solvent system containing hexane/ethyl acetate (9:1) and visualized by immersing the plate in sulfuric acid/methanol reagent followed by heating at 110 °C. Nitro blue tetrazolium (NBT) was obtained from Sigma Chemicals (USA). Brine shrimp (Artemiasalina Cysts) eggs were obtained from Argent Chemical Laboratories, Redmond (USA). The solvents and other chemicals used were of AR grade and were procured from Qualigens Fine Chemicals, Mumbai (India).

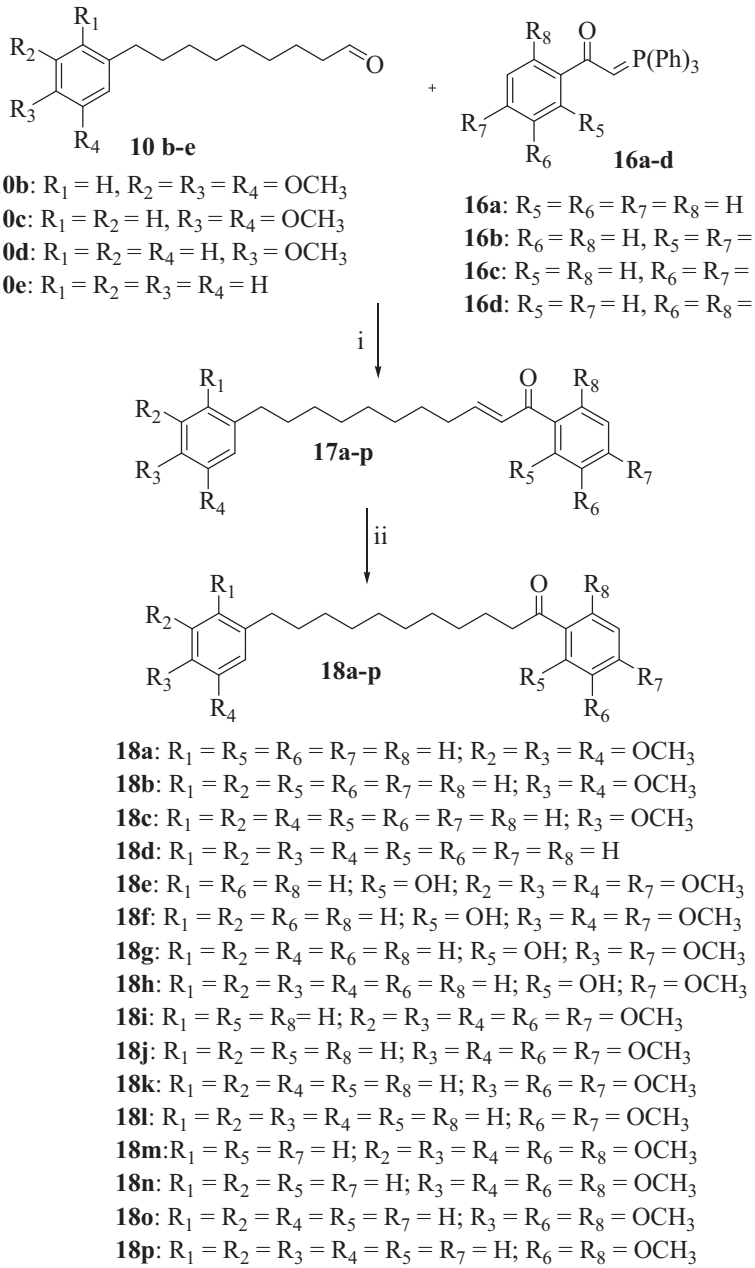
*Methyl 6-hydroxyhexanoate (**2**)*

ε-Caprolactone (30 g, 0.2631 mol) was dissolved in dry methanol (150 mL), treated with 10 drops of conc.H_2SO_4, and the reaction mixture was stirred for 2 h. After completion of reaction, the reaction mixture was poured into water (500 mL) and extracted with chloroform (2 × 250 mL). The combined organic layer was washed with brine solution, dried over Na_2SO_4 and concentrated under vacuum to yield methyl 6-hydroxyhexanoate (32 g, 88%). ^1H NMR ($CDCl_3$, 400 MHz): δ 3.72 (3H, s, OCH_3), 3.53 (2H, t, $J = 7.2$ Hz, H-6), 2.26 (2H, t, $J = 7.6$ Hz, H-2), 1.71–1.66 (2H, m, H-3), 1.54–1.49 (2H, m, H-5), 1.28–1.22 (2H, m, H-4); ^{13}C NMR ($CDCl_3$,100 MHz): δ 171.4 (C-1), 64.1 (C-6), 52.3 (OCH_3), 33.6 (C-2), 32.4 (C-5), 25.3 (C-4), 25.1 (C-3).

*Methyl hex-6-al-1-oate (**3**)*

Methyl 6-hydroxyhexanoate (**2**, 16 g, 0.1095 mol) was dissolved in dichloromethane (450 mL) and treated with Jones reagent (80 mL) adsorbed on silica gel (160 g) in small portions under vigorous stirring. The reaction mixture was then stirred for 3 h., the reaction mixture was filtered and the filtrate was concentrated under vacuum. The crude substance was purified further by column chromatography (silica gel 100–200#, eluent: 15% ethyl acetate /hexane mixtures) to yield methyl 6-al-hexanoate (11.9 g, 76%).

Scheme 5 Synthesis of undecanone analogs (**18a–p**). Reagents and conditions: (i) THF; (ii) H_2-Pd/$CaCO_3$, ethyl acetate



10b: $R_1 = H$, $R_2 = R_3 = R_4 = OCH_3$
10c: $R_1 = R_2 = H$, $R_3 = R_4 = OCH_3$
10d: $R_1 = R_2 = R_4 = H$, $R_3 = OCH_3$
10e: $R_1 = R_2 = R_3 = R_4 = H$

16a: $R_5 = R_6 = R_7 = R_8 = H$
16b: $R_6 = R_8 = H$, $R_5 = R_7 = OCH_3$
16c: $R_5 = R_8 = H$, $R_6 = R_7 = OCH_3$
16d: $R_5 = R_7 = H$, $R_6 = R_8 = OCH_3$

18a: $R_1 = R_5 = R_6 = R_7 = R_8 = H$; $R_2 = R_3 = R_4 = OCH_3$
18b: $R_1 = R_2 = R_5 = R_6 = R_7 = R_8 = H$; $R_3 = R_4 = OCH_3$
18c: $R_1 = R_2 = R_4 = R_5 = R_6 = R_7 = R_8 = H$; $R_3 = OCH_3$
18d: $R_1 = R_2 = R_3 = R_4 = R_5 = R_6 = R_7 = R_8 = H$
18e: $R_1 = R_6 = R_8 = H$; $R_5 = OH$; $R_2 = R_3 = R_4 = R_7 = OCH_3$
18f: $R_1 = R_2 = R_6 = R_8 = H$; $R_5 = OH$; $R_3 = R_4 = R_7 = OCH_3$
18g: $R_1 = R_2 = R_4 = R_6 = R_8 = H$; $R_5 = OH$; $R_3 = R_7 = OCH_3$
18h: $R_1 = R_2 = R_3 = R_4 = R_6 = R_8 = H$; $R_5 = OH$; $R_7 = OCH_3$
18i: $R_1 = R_5 = R_8 = H$; $R_2 = R_3 = R_4 = R_6 = R_7 = OCH_3$
18j: $R_1 = R_2 = R_5 = R_8 = H$; $R_3 = R_4 = R_6 = R_7 = OCH_3$
18k: $R_1 = R_2 = R_4 = R_5 = R_8 = H$; $R_3 = R_6 = R_7 = OCH_3$
18l: $R_1 = R_2 = R_3 = R_4 = R_5 = R_8 = H$; $R_6 = R_7 = OCH_3$
18m: $R_1 = R_5 = R_7 = H$; $R_2 = R_3 = R_4 = R_6 = R_8 = OCH_3$
18n: $R_1 = R_2 = R_5 = R_7 = H$; $R_3 = R_4 = R_6 = R_8 = OCH_3$
18o: $R_1 = R_2 = R_4 = R_5 = R_7 = H$; $R_3 = R_6 = R_8 = OCH_3$
18p: $R_1 = R_2 = R_3 = R_4 = R_5 = R_7 = H$; $R_6 = R_8 = OCH_3$

^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.72 (1H, t, $J = 6.8$ Hz, H-6), 3.72 (3H, s, OCH_3), 2.43 (2H, t, $J = 7.2$ Hz, H-5), 2.24 (2H, t, $J = 7.2$ Hz, H-2), 1.72–1.69 (2H, m, H-3), 1.62–1.60 (2H, m, H-4); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 201.2 (C-6), 176.2 (C-1), 52.4 (OCH_3), 44.2 (C-5), 33.3 (C-2), 24.8 (C-3), 22.3 (C-4).

*General procedure for 7-(substituted phenyl)-hept-6-enoic acid methyl ester (**4a–e**)*

NaH (6 g, 0.248 mol) was suspended in dry tetrahydrofuran (250 mL). The mixture was cooled to 5 °C, and then treated with suitably substituted benzyltriphenyl-phosphonium bromide (0.0765 mol) in small portions for 40 min. After completion of the addition, the reaction mixture was stirred for 30 min. Then Methyl hex-6-al-1-oate (**3**, 9.8 g, 0.06849 mol) dissolved in tetrahydrofuran (50 mL) was slowly added dropwise to the reaction mixture. After completion of addition, the reaction mixture was stirred for 3 h at room temperature. After completion of reaction, the reaction mixture was poured into ice cold water (800 mL) and the mixture was acidified with 2N HCl and extracted with ethyl acetate (2×300 mL). The combined organic layer was washed with brine solution, dried over Na_2SO_4 and

concentrated under vacuum. The crude mixture of the reaction was purified by column chromatography (silica gel 100–200#, eluent: 5% ethyl acetate/hexane) to yield the corresponding 7-(substituted phenyl)-hept-6-enoic acid methyl ester (**4a–e**, 60–75%).

7-(2-methoxy-phenyl)-hept-6-enoic acid methyl ester (**4a**) Oily substance, (11.38 g, 67%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.18 (1H, dd, $J = 3.2$, 8.4 Hz, H-6′), 7.06 (1H, td, $J = 3.2$, 8.4 Hz, H-4′), 6.87 (1H, td, $J = 3.6$, 8.8 Hz, H-5′), 6.71 (1H, dd, $J = 3.6$, 8.4 Hz, H-3′), 6.62 (1H, d, $J = 16.8$ Hz, H-7), 5.82 (1H, td, $J = 16.8$, 7.2 Hz, H-6), 3.74 (3H, s, OCH_3), 3.68 (3H, s, OCH_3), 2.21 (2H, t, $J = 7.2$ Hz, H-2), 1.93 (2H, t, $J = 7.2$ Hz, H-5), 1.68–1.65 (2H, m, H-3), 1.36–1.34 (2H, m, H-4); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 172.6 (C-1), 158.9 (C-2′), 128.6 (C-4′), 128.2 (C-6′), 126.9 (C-1′), 126.3 (C-7), 121.6 (C-6), 120.5 (C-5′), 115.2 (C-3′), 56.3 (OCH_3), 50.6 (OCH_3), 50.1 (C-5), 33.4 (C-2), 32.8 (C-3), 25.6 (C-4); LC-MS: *m/z* 249.3 $(M + H)^+$, 271.3 $(M + Na)^+$.

7-(3,4,5-Trimethoxyphenyl)-hept-6-enoic acid methyl ester (**4b**) Oily substance, (15.2 g, 72%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 6.88 (1H, d, $J = 16.0$ Hz, H-7), 6.21 (2H, s, H-2′, 6′), 6.01 (1H, td, $J = 15.6$, 6.4 Hz, H-6), 3.53 (3H, s, OCH_3), 2.21 (2H, t, $J = 7.6$ Hz, H-2), 1.92 (2H, t, $J = 7.6$ Hz, H-5), 1.62–1.58 (2H, m, H-3), 1.31–1.29 (2H, m, H-4); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 171.2 (C-1), 150.5 (C-3′, 5′), 137.9 (C-4′), 129.4 (C-6), 129.1 (C-1′), 125.4 (C-7), 103.6 (C-2′, 6′), 56.2 (OCH_3), 56.1 (OCH_3), 51.6 (OCH_3), 33.5 (C-2), 33.1 (C-5), 29.5 (C-4), 25.3 (C-3); LC-MS: *m/z* 309.3 $(M + H)^+$, 331.3 $(M + Na)^+$.

7-(3,4-Dimethoxyphenyl)-hept-6-enoic acid methyl ester (**4c**) Oily substance, (14.2 g, 75%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 6.72 (1H, dd, $J = 8.0$, 3.2 Hz, H-6′), 6.69 (1H, d, $J = 3.2$ Hz, H-2′), 6.58 (1H, d, $J = 8$ Hz, H-5′), 6.39 (1H, d, $J = 16.4$ Hz, H-7), 6.01 (1H, td, $J = 15.6$, 6.4 Hz, H-6), 3.52 (6H, s, OCH_3), 3.41 (3H, s, OCH_3), 2.22 (2H, t, $J = 7.6$ Hz, H-2), 1.90 (2H, t, $J = 7.6$ Hz, H-5), 1.62–1.56 (2H, m, H-3), 1.30–1.28 (2H, m, H-4); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 171.2 (C-1), 149.1 (C-3′), 148.8 (C-4′), 128.8 (C-6), 128.1 (C-1′), 125.4 (C-7), 119.3 (C-6′), 115.1 (C-5′), 111.2 (C-2′), 56.1 (OCH_3), 51.6 (OCH_3), 33.4 (C-2), 33.1 (C-5), 29.3 (C-4), 25.4 (C-3); LC-MS: *m/z* 279.2 $(M + H)^+$, 301.3 $(M + Na)^+$.

7-(4-Methoxyphenyl)-hept-6-enoic acid methyl ester (**4d**) Oily compound, (10.2 g, 60%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.09 (2 H, d, $J = 7.6$ Hz, H-2′, 6′), 6.65 (2H, d, $J = 7.2$ Hz, H-3′, 5′), 6.38 (1H, d, $J = 16.4$ Hz, H-7), 6.01 (1H, td, $J = 16.0$, 6.4 Hz, H-6), 3.63 (3H, s, OCH_3), 3.58 (3H, s, OCH_3), 2.21 (2H, t, $J = 7.6$ Hz, H-2), 1.91 (2H, t, $J = 7.6$ Hz, H-5), 1.66–1.62 (2H, m, H-3), 1.32–1.29 (2H, m, H-4); ^{13}C NMR ($CDCl_3$, 100 MHz)**:** δ 171.2 (C-1), 159.2 (C-4′), 128.8 (C-6), 127.3 (C-1′), 127.1 (C-2′,6′), 125.4 (C-7), 113.8 (C-3′, 5′), 55.1 (OCH_3), 51.8 (OCH_3), 33.2 (C-2), 33.0 (C-5), 29.4 (C-4), 25.4 (C-3); LC-MS: *m/z* 249.3 $(M + H)^+$, 271.2 $(M + Na)^+$.

7-(Phenyl)-hept-6-enoic acid methyl ester (**4e**) Oily compound, (10.15 g, 68%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.32 (2H, d, $J = 8.4$ Hz, H-2′, 6′), 7.25 (2H, t, $J = 7.2$ Hz, H-3′, 5′), 7.18 (1H, t, $J = 7.6$ Hz, H-4′), 6.38 (1H, d, $J = 16.4$ Hz, H-7), 6.01 (1H, td, $J = 16.4$, 7.2 Hz, H-6), 3.63 (3H, s, OCH_3), 2.22 (2H, t, $J = 7.6$ Hz, H-2), 1.92 (2H, t, $J = 7.6$ Hz, H-5), 1.68–1.62 (2H, m, H-3), 1.30–1.28 (2H, m, H-4); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 171.2 (C-1), 135.1 (C-1′), 128.8 (C-6), 128.5 (C-3′, 5′), 128.1 (C-4′), 126.2 (C-7), 125.6 (C-2′, 6′), 51.9 (OCH_3), 33.7 (C-2), 33.1 (C-5), 29.3 (C-4), 25.0 (C-3); LC-MS: *m/z* 217.4 $(M-H)^-$.

*General procedure for 7-(substituted phenyl)-heptan-1-ol (**5a–e**)*

Lithium aluminum hydride (3 g, 0.08108 mol) was suspended in dry THF(100 mL), and then the mixture was treated with a solution containing suitable methyl 7-(substituted phenyl)-hept-6-enoic acid methyl esters (**4a–e**, 0.0325 mol) dissolved in 25 ml dry THF drop wise with stirring. After completion of reaction, mixture was poured in to cold water (250 mL), acidified with 2N HCL and extracted with chloroform (2×250 mL).The combined organic layer was washed with brine solution, dried over Na_2SO_4 and concentrated under vacuum. The crude residue was purified by column chromatography (eluent: 15–20% ethyl acetate/hexane) to yield corresponding 7-(substituted phenyl)-heptan-1-ol (**5a–e**, 75–87%).

7-(2-Methoxyphenyl)-heptan-1-ol (**5a**) Oily compound. (6.2 g, 87%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.18 (1H, dd, $J = 3.2$, 8.4 Hz, H-6′), 7.06 (1H, td, $J = 3.2$, 8.4 Hz, H-4′), 6.87 (1H, td, $J = 3.6$, 8.8 Hz, H-5′), 6.71 (1H, dd, $J = 3.6$, 8.4 Hz, H-3′), 3.74 (3H, s, OCH_3), 3.48 (2H, t, $J = 6.8$ Hz, H-1), 2.49 (2H, t, $J = 7.2$ Hz, H-7), 2.02 (2H, t, $J = 7.2$ Hz, H-2), 1.91 (2H, t, $J = 7.2$ Hz, H-5), 1.68–1.65 (4H, m, H-3, 6), 1.36–1.34 (2H, m, H-4); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 158.4 (C-2′), 128.5 (C-4′), 128.2 (C-6′), 126.9 (C-1′), 126.3 (C-7), 121.6 (C-6), 120.5 (C-5′), 115.2 (C-3′), 64.3 (C-1), 56.3 (OCH_3), 50.1 (C-5), 33.4 (C-2), 32.8 (C-3), 25.6 (C-4); LC-MS: *m/z* 223.3 $(M + H)^+$, 245.3 $(M + Na)^+$.

7-(3,4,5-Trimethoxyphenyl)-heptan-1-ol (**5b**) Oily compound, (7.1 g, 7.8%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 6.03 (2H, s, H-2′, 6′), 3.71 (9H, s, OCH_3), 3.53 (2H, t, $J = 7.6$

Hz, H-1), 2.46 (2H, t, $J = 7.2$ Hz, H-7), 2.0 (1H, s, OH), 1.61–1.59 (2H, m, H-6), 1.46–1.42 (2H, m, H-2), 1.28–1.22 (6H, m, H-3, 4, 5); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 149.2 (C-3′), 148.4 (C-5′), 140.6 (C-1′), 131.2 (C-4′), 108.3 (C-2′, 6′), 63.6 (C-1), 56.2 (OCH_3), 36.2 (C-7), 33.4 (C-2), 32.3 (C-6), 30.1 (C-4), 29.8 (C-5), 26.8 (C-3); LC-MS: *m/z* 283.3 $(M + H)^+$, 305.3 $(M + Na)^+$.

7-(3,4-Dimethoxyphenyl)-heptan-1-ol (**5c**) Oily compound, (6.7 g, 82%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 6.58 (1H, dd, $J = 8.4$, 3.6 Hz, H-6′), 6.51 (1H, d, $J = 3.6$ Hz, H-2′), 6.48 (1H, d, $J = 8.4$ Hz, H-5′), 3.73 (6H, s, OCH_3), 3.53 (2H, t, $J = 6.8$ Hz, H-1), 2.45 (2H, t, $J = 7.2$ Hz, H-7), 2.06 (1H, s, OH), 1.63–1.61 (2H, m, H-6), 1.46–1.42 (2H, m, H-2), 1.29–1.26 (6H, m, H-3, 4, 5); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 148.4 (C-3′), 144.8 (C-4′), 133.7 (C-1′), 122.4 (C-6′), 116.9 (C-2′, 5′), 63.6 (C-1), 56.3 (OCH_3), 36.2 (C-7), 33.3 (C-2), 32.6 (C-6), 30.1 (C-4), 29.9 (C-5), 26.4 (C-3); LC-MS: *m/z* 253.3 $(M + H)^+$, 275.3 $(M + Na)^+$, 291.4 $(M + K)^+$.

7-(4-Methoxyphenyl)-heptan-1-ol (**5d**) Oily substance, (5.4 g, 75%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.09 (2H, d, $J = 7.6$ Hz, H-2′, 6′), 6.82 (2H, d, $J = 7.2$ Hz, H-3′, 5′), 3.73 (3H, s, OCH_3), 3.52 (2H, t, $J = 7.2$ Hz, H-1), 2.46 (2H, t, $J = 7.2$ Hz, H-7), 2.1 (1H, s, OH), 1.63–1.61 (2H, m, H-6), 1.46–1.42 (2H, m, H-2), 1.29–1.26 (6H, m, H-3, 4, 5); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 159.6 (C-4′), 132.7 (C-1′), 129.6 (C-2′, 6′), 114.8 (C-3′, 5′), 63.6 (C-1), 56.2 (OCH_3), 36.1 (C-7), 33.4 (C-2), 32.6 (C-6), 30.2 (C-4), 29.9 (C-5), 26.2 (C-3); LC-MS: *m/z* 223.3 $(M + H)^+$, 245.4 $(M + Na)^+$, 261.4 $(M + K)^+$.

7-(Phenyl)-heptan-1-ol (**5e**) Oily compound, (5.0 g, 80 %); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.24 (2H, d, $J = 8.4$ Hz, H-3′, 5′), 7.14 (2 H, t, $J = 7.2$ Hz, H-2′, 6′), 7.09 (1H, t, $J = 7.2$ Hz, H-4′), 3.53 (2H, t, $J = 7.2$ Hz, H-1), 2.46 (2H, t, $J = 7.2$ Hz, H-7), 1.62–1.59 (2H, m, H-6), 1.46–1.42 (2H, m, H-2), 1.29–1.26 (6H, m, H-3, 4, 5); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 139.2 (C-1′), 129.2 (C-2′, 3′, 5′, 6′) 126.2 (C-4′), 63.6 (C-1), 36.0 (C-7), 33.4 (C-2), 32.6 (C-6), 30.3 (C-4), 29.9 (C-5), 26.3 (C-3); LC-MS: *m/z* 193.5 $(M + H)^+$.

*General procedure for 7-(substituted phenyl)-hepan-1-al (**6a–e**)*

Suitable 7-(substituted phenyl)-heptan-1-ol (**5a–e**, 0.02727 mol) compound was dissolved in DMSO (60 mL) and to the mixture was added IBX (7.1 g, 0.02727 mol) portion wise for 20 min. After completion of addition, the reaction mixture was stirred for 2 h. at room temperature. After completion of reaction, the reaction mixture was poured into water (200 mL).The mixture was filtered, the filter bed was washed with chloroform (200 mL). The filtrate was taken in to a separating funnel, separated the organic layer and the aqueous layer was extracted with chloroform (200 mL). The combined organic layer was washed with water, brine solution, dried over Na_2SO_4 and concentrated under vacuum. The crude residue was purified by column chromatography on silica gel (15% ethyl acetate/hexane) to get corresponding 7-(substituted phenyl)-heptan-1-al (**6a–e**, 82–88%).

7-(2-Methoxyphenyl)-heptan-1-al (**6a**) Oily compound, (4.9 g, 83%.); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.72 (1H, t, $J = 6.8$ Hz, H-1), 7.02 (1H, dd, $J = 3.6$, 8.8 Hz, H-6′), 6.95 (1H, td, $J = 3.2$, 8.4 Hz, H-4′), 6.72 (1H, td, $J = 3.6$, 8.8 Hz, H-5′), 6.68 (1H, dd, $J = 3.2$, 8.4 Hz, H-3′), 3.73 (3H, s, OCH_3), 2.52 (2H, t, $J = 7.2$ Hz, H-2), 2.41 (2H, t, $J = 7.2$ Hz, H-7), 1.66–1.62(4H, m, H-3, 6), 1.28–1.22 (4H, m, H-4, 5); ^{13}C NMR ($CDCl_3$,100 MHz): δ 200.8 (C-1), 162.1 (C-2′), 129.6 (C-4′), 126.1 (C-6′), 125.3 (C-1′), 121.8 (C-5′), 116.6 (C-2′), 56.3 (OCH_3), 43.8 (C-7), 32.8 (C-2), 29.9 (C-3), 29.7 (C-6), 25.6 (C-5), 22.8 (C-4); LC-MS: *m/z* 221.4 $(M + H)^+$, 243.2 $(M + Na)^+$.

7-(3,4,5-Trimethoxyphenyl)-heptan-1-al (**6b**) Oily compound, (6.2 g, 82%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.71 (1H, t, $J = 7.2$ Hz, H-1), 6.08 (2H, s, H-2′, 6′), 3.73 (9H, s, OCH_3), 2.52 (2H, t, $J = 7.2$ Hz, H-7), 2.41 (2H, t, $J = 7.2$ Hz, H-2), 1.69–1.64 (4H, m, H-3, 6), 1.32–1.28 (4H, m, H-4, 5); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 200.6 (C-1), 148.6 (C-3′, 5′), 134.6 (C-1′), 130.2 (C-4′), 106.3 (C-2′, 6′), 44.6 (C-2), 36.4 (C-7), 32.5 (C-6), 29.6 (C-4, 5), 22.5 (C-3); LC-MS: *m/z* 281.3 $(M + H)^+$, 303.4 $(M + Na)^+$, 319.3 $(M + K)^+$.

7-(3,4-Dimethoxyphenyl)-heptan-1-al (**6c**) Oily compound, (6.0 g, 88%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.72 (1H, t, $J = 7.2$ Hz, H-1), 6.58 (1H, td, $J = 7.6$, 3.2 Hz, H-6′), 6.52 (1H, d, $J = 3.2$ Hz, H-2′), 6.36 (1H, d, $J = 7.6$ Hz, H-5′), 3.73 (6H, s, OCH_3), 2.52 (2H, t, $J = 7.2$ Hz, H-7), 2.42 (2H, t, $J = 7.2$ Hz, H-2), 1.69–1.64 (4H, m, H-3, 6), 1.32–1.29 (4H, m, H-4, 5); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 200.6 (C-1), 148.1 (C-3′), 145.6 (C-4′), 133.9 (C-1′), 122.6 (C-6′), 115.6 (C-2′, 5′), 56.2 (OCH_3), 44.6 (C-2), 36.4 (C-7), 32.5 (C-6), 29.8 (C-4), 29.6 (C-5), 22.4 (C-3); LC-MS: *m/z* 251.3 $(M + H)^+$, 273.4 $(M + Na)^+$, 289.3 $(M + K)^+$.

7-(4-Methoxyphenyl)-heptan-1-al (**6d**) Oily compound (5.0 g, 85%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.72 (1H, t, $J = 7.2$ Hz, H-1), 7.09 (2H, d, $J = 7.2$ Hz, H-2′, 6′), 6.82 (2H, d, $J = 7.2$ Hz, H-3′, 5′), 3.72 (3H, s, OCH_3), 2.52 (2 H, t, $J = 7.2$ Hz, H-7), 2.42 (2H, t, $J = 7.2$ Hz, H-2), 1.69–1.62

(4H, m, H-3, 6), 1.32–1.29 (4H, m, H-4, 5); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 200.6 (C-1), 158.3 (C-4′), 132.6 (C-1′), 129.6 (C-2′, 6′), 114.8 (C-3′, 5′), 54.6 (OCH_3), 44.6 (C-2), 36.4 (C-7), 32.5 (C-6), 29.8 (C-4), 29.6 (C-5), 22.4 (C-3); LC-MS: *m/z* 219.4 $(M-H)^-$.

7-(Phenyl)-heptane-1-al (**6e**) Oily substance (4.5 g, 87%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.74 (1H, s, H-1), 7.24 (2H, d, $J = 8.4$ Hz, H-3′, 5′), 7.14 (2H, t, $J = 7.6$ Hz, H-2′, 6′), 7.06 (1H, t, $J = 7.6$ Hz, H-4′), 2.52 (2H, t, $J = 7.2$ Hz, H-7), 2.42 (2H, t, $J = 7.2$ Hz, H-2), 1.69–1.63 (4 H, m, H-3, 6), 1.32–1.28 (4 H, m, H-4, 5); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 200.6 (C-1), 140.2 (C-1′), 127.2 (C-2′, 3′, 5′, 6′), 126.8 (C-4′), 44.6 (C-2), 36.4 (C-7), 32.9 (C-6), 29.9 (C-4), 29.6 (C-5), 22.6 (C-3); LC-MS: *m/z* 191.3 $(M + H)^+$.

*General procedure for 9-(Substituted phenyl)-nona-2-enoic acid ethyl ester (**7a–e**)*

A mixture of suitable7-(substituted phenyl)-heptan-1-al (**6a–6e**, 0.02045 mol), dry THF (50 mL) and ethyl triphenylphosphorane (7.1 g, 0.02045 mol) was refluxed for 4–5 h. After completion of reaction, the reaction mixture was concentrated under vacuum. The crude mixture was purified by column chromatography on silica gel (5–10% ethyl acetate/hexane) to yield the corresponding 9-(substituted phenyl)-nona-2-enoic acid ethyl ester (**7a–7e**, 65–74%).

9-(2-MethoxyPhenyl)-nona-2-enoic acid ethyl ester (**7a**) Oily substance, (4.1 g, 69%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.04 (1H, dd, $J = 3.6$, 8.8 Hz, H-6′), 6.89 (1H, td, $J =$ 17.2, 7.6 Hz, H-3), 6.85 (1H, td, $J = 3.2$, 8.4 Hz, H-4′), 6.71 (1H, td, $J = 3.6$, 8.8 Hz, H-5′), 6.66 (1H, dd, $J = 3.2$, 8.4 Hz, H-3′), 5.81 (1H, t, $J = 17.2$ Hz, H-2), 4.12 (2H, q, $J =$ 6.8 Hz, OCH_2), 3.73 (3H, s, OCH_3), 2.52 (2H, t, $J = 7.6$ Hz, H-9), 1.93 (2H, t, $J = 7.2$ Hz, H-4), 1.68–1.64 (2H, m, H-8), 1.35–1.32 (2H, m, H-5), 1.31 (3H, t, $J = 6.4$ Hz, CH_2–$\underline{CH_3}$), 1.29–1.22 (4H, m, H-6, 7); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 165.3 (C-1), 161.6 (C-2′), 129.4 (C-4′), 126.8 (C-6′), 126.1 (C-3), 121.1 (C-1′), 120.8 (C-2), 118.3 (C-5′), 114.6 (C-3′), 59.6 (OCH_2), 56.2 (OCH_3), 32.8 (C-9), 30.5 (C-4), 30.1 (C-8), 25.6 (C-5, 6, 7), 13.8 (CH_2–$\underline{CH_3}$); LC-MS: *m/z* 291.3 $(M + H)^+$, 313.4 $(M + Na)^+$.

9-(3,4,5-Trimethoxyphenyl)-nona-2-enoic acid ethyl ester (**7b**) Oily substance, (4.6 g, 65%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 6.82 (1H, td, $J = 16.8$, 7.6 Hz, H-3), 6.02 (2H, s, H-2′, 6′), 5.81 (1H, t, $J = 16.8$ Hz, H-2), 4.12 (2H, q, $J =$ 6.4 Hz, OCH_2), 3.65 (9H, s, OCH_3), 2.51 (2H, t, $J = 7.2$ Hz, H-9), 1.92 (2H, t, $J = 7.6$ Hz, H-4), 1.62–1.66 (2H, m, H-8), 1.35v1.32 (2H, m, H-5), 1.30 (3H, t, $J = 7.2$ Hz, $CH_2\underline{CH_3}$), 1.29–1.27 (4H, m, H-6, 7); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 166 (C-1), 150.4 (C-3′, 5′), 149.3 (C-3), 136.1 (C-1′), 133.0 (C-4′), 121.2 (C-2), 105.8 (C-2′, 6′), 61.2 (OCH_2), 56.4 (OCH_3), 36.1 (C-9), 33.1 (C-4), 31.5 (C-8), 29.8 (C-6), 29.7 (C-7), 29.5 (C-5), 14.3 (CH_2CH_3); LC-MS: *m/z* 351.3 $(M + H)^+$, 373.4 $(M + Na)^+$.

9-(3,4-Dimethoxyphenyl)-nona-2-enoic acid ethyl ester (**7c**) Oily substance, (4.8 g, 74%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 6.82 (1H, td, $J = 16.8$, 7.6 Hz, H-3), 6.60 (1H, dd, $J = 8.0$, 3.2 Hz, H-5′), 6.53 (1H, d, $J = 3.2$ Hz, H-2′), 6.51 (1H, d, $J = 8.0$ Hz, H-6′), 5.81 (1H, t, $J = 16.8$ Hz, H-2), 4.12 (2H, q, $J = 6.4$ Hz, OCH_2), 3.61 (6 H, s, OCH_3), 2.50 (2H, t, $J = 7.6$ Hz, H-9), 1.92 (2H, t, $J = 7.6$ Hz, H-4), 1.65–1.62 (2H, m, H-8), 1.34–1.32 (2H, m, H-5), 1.30 (3H, t, $J = 7.2$ Hz, OCH_2CH_3), 1.29 (4H, s, H-6, 7); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 166.1 (C-1), 149.5 (C-3), 149.4 (C-3′), 147.1 (C-4′), 132.3 (C-1′), 121.8 (C-2), 115.3 (C-2′, 5′), 61.4 (OCH_2), 56.2 (OCH_3), 36.4 (C-9), 33.2 (C-4), 31.3 (C-8), 29.8 (C-5), 29.7 (C-6), 29.3 (C-7), 14.5 ($CH_2\underline{CH_3}$); LC-MS: *m/z* 321.3 $(M + H)^+$, 343.4 $(M + Na)^+$.

9-(3-Methoxyphenyl)-nona-2-enoic acid ethyl ester (**7d**) Oily substance (4.2 g, 72%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.05 (2H, d, $J = 7.2$ Hz, H-2′, 6′), 6.82 (1H, td, $J = 16.8$, 7.6 Hz, H-3), 6.74 (2H, d, $J = 7.2$ Hz, H-3′, 5′), 5.81 (1H, t, $J = 16.8$ Hz, H-2), 4.19 (2H, q, $J = 6.8$ Hz, OCH_2), 3.71 (3H, s, OCH_3), 2.51 (2H, t, $J = 8.0$ Hz, H-9), 1.93 (2H, t, $J = 7.6$ Hz, H-4), 1.64–1.62 (2H, m, H-8), 1.35–1.33 (2H, m, H-5), 1.30 (3H, t, $J = 7.2$ Hz, $CH_2\underline{CH_3}$), 1.29–1.27 (4H, m, H-6, 7); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 166.1 (C-1), 157.9 (C-4′), 149.6 (C-3), 131.3 (C-1′), 129.2 (C-2′, 6′), 121.3 (C-2), 114.6 (C-3′, 5′), 61.4 (OCH_2), 55.8 (OCH_3), 36.2 (C-9), 33.3 (C-4), 31.4 (C-8), 29.8 (C-6), 29.7 (C-5), 29.3 (C-7), 14.2 (CH_2–$\underline{CH_3}$); LC-MS: *m/z* 291.3 $(M + H)^+$, 313.4 $(M + Na)^+$.

9-(Phenyl)-nona-2-enoic acid ethyl ester (**7e**) Oily compound, (3.9 g, 73%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.21 (2H, d, $J = 8.4$ Hz, H-3′, 5′), 7.16 (2H, t, $J = 8.0$ Hz, H-2′, 6′), 7.06 (1H, t, $J = 7.6$ Hz, H-4′), 6.82 (1H, td, $J = 16.8$, 7.6 Hz, H-3), 5.81 (1H, t, $J = 16.8$ Hz, H-2), 4.19 (2H, q, $J =$ 7.2 Hz, OCH_2), 2.55 (2H, t, $J = 7.6$ Hz, H-9), 1.95 (2H, t, $J = 7.6$ Hz, H-4), 1.66–1.62 (2H, m, H-8), 1.35–1.33 (2H, m, H-5), 1.30 (3H, q, $J = 7.2$ Hz, $CH_2\underline{CH_3}$), 1.29–1.26 (4H, m, H-6, 7); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 166.1 (C-1), 149.7 (C-3), 138.6 (C-1′), 128.6 (C-2′, 6′), 128.2 (C-3′, 5′), 126.3 (C-4′), 121.9 (C-2), 61.4 (CH_2), 36.2 (C-9), 33.3 (C-4), 31.4 (C-8), 29.8 (C-6), 29.6 (C-5), 29.4 (C-7), 14.2 (CH_2–$\underline{CH_3}$); LC-MS: *m/z* 261.3 $(M + H)^+$, 283.5 $(M + Na)^+$.

*General procedure for 9-(substituted phenyl)-nonanoic acid ethyl ester (**8a–e**)*

A mixture of suitable 9-(substituted phenyl)-nona-2-enoic acid ethyl esters (**7a–e**, 0.01 mol), ethyl acetate (40 mL) and 5% palladium on $CaCO_3$ (10 mg) was taken in a RB flask and contents were vigorously stirred under H_2 atmosphere for 2 h. After completion of reaction, the reaction mixture was filtered on celite, washed with ethyl acetate and the filtrate was concentrated under vacuum to obtain the corresponding 9-(substituted phenyl)-nonanoic acid ethyl ester (**8a–e**, 85–90%).

9-(2-Methoxyphenyl)-nonanoic acid ethyl ester (**8a**) Oily substance, (3.6 g, 90%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.04 (1H, dd, $J = 3.6$, 8.8 Hz, H-6′), 6.85 (1H, td, $J = 3.2$, 8.4 Hz, H-4′), 6.71 (1H, td, $J = 3.6$, 8.8 Hz, H-5′), 6.66 (1H, dd, $J = 3.2$, 8.4 Hz, H-3′), 4.18 (2H, q, $J = 6.8$ Hz, OCH_2), 3.82 (3H, s, OCH_3), 3.73 (3H, s, OCH_3), 2.51 (2H, t, $J =$ 7.6 Hz, H-9), 2.22 (2H, t, $J = 7.2$ Hz, H-2), 1.68–1.66 (2H, m, H-3), 1.63–1.61 (2H, m, H-8), 1.31 (3H, t, $J = 6.8$ Hz, $OCH_2\underline{CH_3}$), 1.29–1.23 (8H, m, H-4, 5, 6, 7); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 172.1 (C-1), 162.1 (C-2′), 130.3 (C-6′), 127.6 (C-4′), 125.1 (C-1′), 121.6 (C-5′), 114.2 (C-3′), 59.6 (OCH_2), 56.1 (OCH_3), 33.8 (C-2), 32.8 (C-8), 30.4 (C-6), 29.9 (C-7), 29.7 (C-4), 25.6 (C-9), 25.4 (C-3), 13.8 ($OCH_2\underline{CH_3}$); LC-MS: *m/z* 293.3 $(M + H)^+$, 315.3 $(M + Na)^+$.

9-(3,4,5-Trimethoxyphenyl)-nonanoic acid ethyl ester (**8b**) Oily compound, (3.0 g, 90%); ^{1}H NMR (d_6-DMSO, 400 MHz): δ 6.08 (2H, s, H-2′, 6′), 4.10 (2H, q, $J = 6.8$ Hz, OCH_2), 3.63 (9H, s, OCH_3), 2.55 (2H, t, $J = 6.8$ Hz, H-9), 2.25 (2H, t, $J = 7.2$ Hz, H-2), 1.72–1.68 (2H, m, H-3), 1.65–1.62 (2H, m, H-8), 1.30 (3H, t, $J = 6.8$ Hz, $OCH_2\underline{CH_3}$), 1.29–1.28 (8H, m, H-4, 5, 6, 7); ^{13}C NMR (d_6-DMSO, 100 MHz): δ 173.2 (C-1), 150.4 (C-3′, 5′), 136.4 (C-1′), 133.5 (C-4′), 105.9 (C-2′, 6′), 61.4 (OCH_2), 58.4 (OCH_3), 55.2 (OCH_3), 36.9 (C-9), 33.7 (C-8), 31.3 (C-2), 29.9 (C-6), 29.7 (C-5), 29.4 (C-4), 29.1 (C-7), 25.2 (C-3), 14.1 (OCH_2–$\underline{CH3}$); LC-MS: *m/z* 353.3 $(M + H)^+$, 375.3 $(M + Na)^+$, 391.4 $(M + K)^+$.

9-(3,4-Dimethoxyphenyl)-nonanoic acid ethyl ester (**8c**) Oily compound, (2.8 g, 89%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 6.61 (1H, dd, $J = 8.4$, 3.6 Hz, H-6′), 6.55 (1H, d, $J = 3.6$ Hz, H-2′), 6.51 (1H, d, $J = 8.4$ Hz, H-5′), 4.12 (2H, q, $J =$ 6.8 Hz, OCH_2), 3.63 (6H, s, OCH_3), 2.55 (2H, t, $J = 6.8$ Hz, H-9), 2.25 (2H, t, $J = 7.2$ Hz, H-2), 1.72–1.69 (2H, m, H-3), 1.65–1.62 (2H, m, H-8), 1.30 (3H, t, $J = 7.2$ Hz, $OCH_2\underline{CH_3}$), 1.29–1.25 (8H, m, H-4, 5, 6, 7); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 173.2 (C-1), 149.6 (C-3′), 147.2 (C-4′), 132.6 (C-1′), 121.1 (C-6′), 115.5 (C-2′), 113.3 (C-5′), 61.4 (OCH_2), 56.3 (OCH_3), 36.2 (C-9), 33.3 (C-2), 31.9 (C-8), 29.7 (C-6), 29.4 (C-5), 29.3 (C-7), 29.1 (C-4), 25.3 (C-3), 14.2 ($OCH_2\underline{CH_3}$); LC-MS: *m/z* 323.3 $(M + H)^+$, 345.4 $(M + Na)^+$.

9-(4-Methoxyphenyl)-nonanoic acid ethyl ester (**8d**) Oily compound, (2.5 g, 85%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.05 (2H, d, $J = 7.6$ Hz, H-2′, 6′), 6.72 (2H, d, $J = 7.2$ Hz, H-3′, 5′), 4.12 (2H, q, $J = 6.8$ Hz, OCH_2), 3.63 (3H, s, OCH_3), 2.55 (2H, t, $J = 6.8$ Hz, H-9), 2.26 (2H, t, $J = 7.2$ Hz, H-2), 1.71–1.68 (2H, m, H-3), 1.65–1.62 (2H, m, H-8), 1.30 (3H, t, $J = 6.8$ Hz, OCH_2CH_3), 1.29–1.26 (8H, m, H-4, 5, 6, 7); ^{13}C NMR ($CDCl_3$, 100 MHz)**:** δ 173.2 (C-1), 157.8 (C-4′), 131.9 (C-1′), 129.1 (C-2′, 6′), 114.2 (C-3′, 5′), 61.4 (OCH_2), 55.8 (OCH_3), 36.0 (C-9), 33.3 (C-2), 31.7 (C-8), 29.9 (C-6), 29.7 (C-5), 29.4 (C-7), 29.1 (C-4), 25.1 (C-3), 14.2 ($OCH_2\underline{CH_3}$); LC-MS: *m/z* 293.4 $(M + H)^+$, 315.3 $(M + Na)^+$.

9-(Phenyl)-nonanoic acid ethyl ester (**8e**) Oily substance, (2.3 g, 87%); **^{1}**H NMR ($CDCl_3$, 400 MHz): δ 7.21 (2H, d, J = 7.6 Hz, H-3′, 5′), 7.12 (2H, t, $J = 7.2$ Hz, H-2′, 6′), 7.01 (1H, t, $J = 7.6$ Hz, H-4′), 4.12 (2H, q, $J = 6.8$ Hz, CH_2), 2.55 (2H, t, $J = 6.8$ Hz, H-9), 2.25 (2H, t, $J = 7.2$ Hz, H-2), 1.72–1.68 (2H, m, H-3), 1.66–162 (2H, m, H-8), 1.29–1.24 (8H, m, H-4, 5, 6, 7); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 173.2 (C-1), 138.6 (C-1′), 128.7 (C-2′, 6′), 128.0 (C-3′, 5′), 126.2 (C-4′), 61.4 (OCH_2), 36.3 (C-9), 33.3 (C-2), 31.9 (C-8), 29.9 (C-6), 29.4 (C-5), 29.3 (C-7), 29.1 (C-4), 25.5 (C-3), 14.2 (OCH_2–$\underline{C}H_3$); LC-MS: *m/z* 263.3 $(M + H)^+$, 285.3 $(M + Na)^+$.

*General procedure for 9-(substituted phenyl)-nonane-1-ol (**9a–e**)*

Lithium aluminum hydride (1.1 g, 0.0299 mol) was suspended in dry THF (20 mL) and treated with a solution of suitable 9-(substituted phenyl)-nonanoic acid ethyl esters (**8a–e** 0.01198 mol) in THF (5 mL) was added slowly drop wise for 15 min. Then the reaction mixture was stirred for 2 h. After completion of reaction, the reaction mixture was poured into water (100 mL), acidified with 2N HCl and extracted with chloroform (2×250 mL). The combined organic layer was washed with brine solution, dried over Na_2SO_4 and concentrated under vacuum. The crude residue was purified by column chromatography on silica gel (20 % ethyl acetate/hexane) to yield the corresponding 9-(substituted phenyl)-nonan-1-ol (**9a–e**, 80–85%).

9-(2-Methoxyphenyl)-nonan-1-ol (**9a**) Oily compound, (2.51 g, 83%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.04 (1H, dd, $J = 3.6$, 8.8 Hz, H-6′), 6.85 (1H, td, $J = 3.2$, 8.4 Hz, H-4′),

6.71 (1H, td, $J = 3.6$, 8.8 Hz, H-5′), 6.66 (1H, dd, $J = 3.2$, 8.4 Hz, H-3′), 3.73 (3H, s, OCH_3), 3.52 (2H, t, $J = 7.2$ Hz, H-1), 2.51 (2H, t, $J = 7.6$ Hz, H-9), 1.68–1.63 (2H, m, H-8), 1.46–1.42 (2H, m, H-2), 1.26–1.21 (10H, m, H-3, 4, 5, 6, 7); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.1 (C-2′), 130.4 (C-6′), 127.3 (C-4′), 126.1 (C-1′), 121.8 (C-5′), 114.6 (C-3′), 64.2 (C-1), 56.3 (OCH_3), 33.4 (C-2), 32.8 (C-8), 30.4 (C-4, 5, 6), 29.8 (C-7), 26.4 (C-3), 25.9 (C-9); LC-MS: *m/z* 241.4 $(M-H)^-$.

9-(3,4,5-Trimethoxyphenyl)-nonan-1-ol (**9b**) Oily compound, (3.2 g, 85%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 6.06 (2H, s, H-2′, 6′), 3.63 (9H, s, OCH_3), 3.52 (2H, d, $J = 7.2$ Hz, H-1), 2.55 (2H, t, $J = 6.8$ Hz, H-9), 2.06 (1H, t, $J = 4.8$ Hz, OH), 1.65–1.62 (2H, m, H-8), 1.48–1.45 (2H, m, H-2), 1.29–1.26 (10H, m, H-3, 4, 5, 6, 7); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 150.6 (C-3′, 5′), 136.0 (C-1′), 133.4 (C-4′), 105.9 (C-2′, 6′), 62.5 (C-1), 58.5 (OCH_3), 58.2 (OCH_3), 36.3 (C-9), 32.3 (C-8), 31.6 (C-2), 29.7 (C-4, 5, 6), 29.4 (C-7), 25.6 (C-9); LC-MS: *m/z* 311.3 $(M + H)^+$, 333.4 $(M + Na)^+$.

9-(3,4-Dimethoxyphenyl)-nonan-1-ol (**9c**) Oily substance, (2.7 g, 80%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 6.61 (1H, dd, $J = 8.4$, 3.6 Hz, H-6′), 6.55 (1H, d, $J = 3.2$ Hz, H-2′), 6.51 (1H, d, $J = 8.4$ Hz, H-5′), 3.73 (6H, s, OCH_3), 3.52 (2H, t, $J = 6.8$ Hz, H-1), 2.55 (2H, t, $J = 7.2$ Hz, H-9), 2.1 (1H, t, $J = 6.8$ Hz, OH), 1.65–1.62 (2H, m, H-8), 1.46–1.42 (2H, m, H-2), 1.29–1.26 (10H, m, H-3, 4, 5, 6, 7); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 149.6 (C-3′), 147.6 (C-4′), 132.5 (C-1′), 121.0 (C-6′), 115.2 (C-2′), 113.9 (C-5′), 62.5 (C-1), 58.5 (OCH_3), 36.3 (C-9), 32.3 (C-2), 31.6 (C-8), 29.7 (C-4, 5, 6), 29.3 (C-7), 25.7 (C-3); LC-MS: *m/z* 281.3 $(M + H)^+$, 303.4 $(M + Na)^+$.

9-(4-Methoxyphenyl)-nonan-1-ol (**9d**) Oily substance, (2.4 g, 81%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.05 (2H, d, $J = 8.4$ Hz, H-2′, 6′), 6.72 (2H, d, $J = 7.6$ Hz, H-3′, 5′), 3.73 (3H, s, OCH_3), 5.52 (2H, t, $J = 7.2$ Hz), 2.51 (2H, t, $J = 6.8$ Hz, H-9), 2.1 (1H, t, $J = 6.4$ Hz, OH), 1.65–1.63 (2H, m, H-8), 1.46–1.42 (2H, m, H-2), 1.29–1.22 (10H, m, H-3, 4, 5, 6, 7); ^{13}C NMR (d_6-DMSO, 100 MHz): δ 157.8 (C-4′), 131.9 (C-1′), 129.0 (C-2′, 6′), 114.9 (C-3′, 5′), 62.5 (C-1), 58.5 (OCH_3), 36.3 (C-9), 32.3 (C-8), 31.2 (C-2), 29.7 (C-4, 5, 6), 29.3 (C-7), 25.6 (C-3); LC-MS: *m/z* 249.5 $(M-H)^-$.

9-(Phenyl)-nonan-1-ol (**9e**) Oily compound, (2.2 g, 84 %); ^{1} H NMR ($CDCl_3$, 400 MHz): δ 7.21 (2H, d, $J = 7.6$ Hz, H-2′, 6′), 7.12 (2H, t, $J = 7.6$ Hz, H-3′, 5′), 7.08 (1H, t, $J = 7.2$ Hz, H-4′), 3.52 (2H, t, $J = 8.4$ Hz, H-1), 2.55 (2H, t, $J = 8.0$ Hz, H-9), 2.02 (1H, t, $J = 5.2$ Hz, OH), 1.65–1.62 (2H, m, H-8), 1.48–1.44 (2H, m, H-2), 1.29–1.21 (10H, m, H-3, 4, 5, 6, 7); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 138.6 (C-1′), 128.7 (C-2′, 6′), 128.2 (C-3′, 5′), 126.0 (C-4′), 62.5 (C-1), 36.3 (C-9), 32.3 (C-2), 30.6 (C-8), 29.7 (C-4, 5, 6), 29.3 (C-7), 25.7 (C-3); LC-MS: *m/z* 221.3 $(M + H)^+$, 243.4 $(M + Na)^+$.

*General procedure for 9-(substituted phenyl)-nonane-1-al (**10a–e**)*

To a mixture of 9-(substituted phenyl)-nonan-1-ol compounds (**9a–e**, 0.01 mol) in DMSO (20 mL) in a 100 mL R. B flask was added IBX (0.01 mol) slowly portion wise and the reaction mixture was then stirred for 3 h. After completion of reaction, the reaction mixture was poured into water (100 mL) and chloroform (100 mL).The mixture was kept under stirring for 10 min and then filtered, and the filter bed washed with chloroform (100 mL). The organic layer was separated. The aqueous layer was extracted with chloroform (100 mL) and the combined the organic layer was washed with water, brine solution, dried over Na_2SO_4 and concentrated under vacuum. The crude residue was purified by column chromatography (15% ethyl acetate/hexane eluent) to obtain the corresponding 9-(substituted phenyl)-nonan-1-al (**10a–10e**, 76–82%).

9-(2-Methoxyphenyl)-nonan-1-al (**10a**) Oily substance, (2.0 g, 81%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.72 (1H, s, H-1) 7.04 (1H, dd, $J = 3.6$, 8.8 Hz, H-6′), 6.85 (1H, td, $J = 3.2$, 8.4 Hz, H-4′), 6.71 (1H, td, $J = 3.6$, 8.8 Hz, H-5′), 6.66 (1H, dd, $J = 3.2$, 8.4 Hz, H-3′), 3.73 (3H, s, OCH_3), 2.51 (2H, t, $J = 7.2$ Hz, H-9), 2.46 (2H, t, $J = 7.6$ Hz, H-2), 1.68–1.66 (4H, m, H-3, 8), 1.29–1.23 (8H, m, H-4, 5, 6, 7); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 201.6 (C-1), 162.6 (C-2′), 130.2 (C-6′), 126.7 (C-4′), 125.6 (C-1′), 121.1 (C-5′), 114.6 (C-3′), 56.4 (OCH_3), 44.2 (C-2), 32.8 (C-8), 30.4 (C-6), 30.0 (C-5), 29.9 (C-7), 29.8 (C-4), 25.9 (C-9), 22.6 (C-3); LC-MS: *m/z* 249.2 $(M + H)^+$, 271.3 $(M + Na)^+$.

9-(3,4,5-Trimethoxyphenyl)-nonan-1-al (**10b**) Oily compound, (2.3 g, 76%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.71 (1H, s, H-1), 6.06 (2H, s, H-2′, 6′), 3.65 (9H, s, OCH_3), 2.55 (2H, t, $J = 7.6$ Hz, H-9), 2.40 (2H, t, $J = 7.2$ Hz, H-2), 1.66–1.62 (4H, m, H-3, 8), 1.29–1.22 (8H, m, H-4, 5, 6, 7); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 202.6 (C-1), 150.1 (C-3′, 5′), 136.6 (C-1′), 133.5 (C-4′), 105.5 (C-2′, 6′), 58.5 (OCH_3), 58.3 (OCH_3), 43.6 (C-2), 36.5 (C-9), 31.4 (C-8), 29.6 (C-5), 29.4 (C-6), 29.3 (C-4), 22.2 (C-3); LC-MS: *m/z* 309.3 $(M + H)^+$, 331.4 $(M + Na)^+$.

9-(3,4-Dimethoxyphenyl)-nonan-1-al (**10c**) Oily compound, (2.3 g, 82 %); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.71 (1H, s, H-1), 6.64 (1H, dd, $J = 8.0$, 3.6 Hz, H-6′), 6.59 (1H, d, $J = 3.6$ Hz, H-2′), 6.51 (1H, d, $J = 8.0$ Hz, H-5′), 3.63 (6H, s, OCH_3), 2.55 (2H, t, $J = 6.8$ Hz, H-9), 2.40 (2H, t, $J = 7.2$ Hz, H-2), 1.66–1.61 (4H, m, H-3, 8), 1.29–1.23

(8H, m, H-4, 5, 6, 7); ^{13}C NMR (d_6-DMSO, 100 MHz): δ 202.6 (C-1), 149.6 (C-3′), 147.6 (C-4′), 132.5 (C-1′), 121.0 (C-6′), 115.2 (C-5′), 113.1 (C-2′), 58.3 (OCH_3), 43.6 (C-2), 36.5 (C-9), 31.3 (C-8), 29.7 (C-5, 6), 29.3 (C-7), 29.2 (C-4), 22.3 (C-3); LC-MS: *m/z* 279.3 $(M + H)^+$, 301.4 $(M + Na)^+$, 317.4 $(M + K)^+$.

9-(4-Methoxyphenyl)-nonan-1-al (**10d**) Oily substance, (1.9 g, 78 %); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.71 (1H, s, H-1), 7.01 (2H, d, $J = 8.0$ Hz, H-2′, 6′), 6.69 (2H, d, $J = 7.6$ Hz, H-3′, 5′), 3.63 (3H, s, OCH_3), 2.55 (2H, t, $J = 7.2$ Hz, H-9), 2.40 (2H, t, $J = 7.2$ Hz, H-2), 1.66–1.59 (4H, m, H-3, 8), 1.28–1.24 (8H, m, H-4, 5, 6, 7); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 202.6 (C-1), 157.6 (C-4′), 131.9 (C-1′), 129.1 (C-2′, 6′), 114.2 (C-3′, 5′), 58.5 (OCH_3), 43.6 (C-2), 36.3 (C-9), 31.0 (C-8), 29.7 (C-5, 6), 29.4 (C-7), 29.3 (C-4), 22.4 (C-3); LC-MS: *m/z* 249.2 $(M + H)^+$, 271.4 $(M + Na)^+$.

9-(Phenyl)-nonan-1-al (**10e**) Oily compound, (1.7 g, 80 %); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.72 (1H, s, H-1), 7.21 (2H, d, $J = 7.6$ Hz, H-2′, 6′), 7.12 (2H, t, $J = 7.2$ Hz, H-3′, 5′), 7.01 (1H, t, $J = 7.6$ Hz, H-4′), 2.55 (2H, t, $J = 6.8$ Hz, H-9), 2.42 (2H, t, $J = 7.2$ Hz, H-2), 1.67–1.62 (4H, m, H-3, 8), 1.26–1.22 (8H, m, H-4, 5, 6, 7); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 202.6 (C-1), 138.1 (C-1′), 128.7 (C-2′, 6′), 128.4 (C-3′, 5′), 126.2 (C-4′), 43.6 (C-2), 36.3 (C-9), 31.3 (C-8), 29.7 (C-5,6), 29.3 (C-7), 29.2 (C-4), 22.4 (C-3); LC-MS: *m/z* 217.5 $(M-H)^-$.

*11-(2-Methoxyphenyl)-undec-2-en-1-oic acid ethyl ester (**11**)*

A mixture of 9-(2-methoxyphenyl)-nonan-1-al (**10a**, 1 g, 4.032 mmol), dry THF (20 mL) and ethyl triphenylphosphorane (1.4 g, 4.032 mmol) in a RB flask was refluxed for 3 h. After completion of reaction, the reaction mixture was concentrated under vacuum. The crude compound was purified by column chromatography on silica gel (5% ethyl acetate/hexane) to obtain 11-(2-methoxyphenyl)-undec-2-enoic acid ethyl ester (**11**, 0.318 g, 68%,). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.04 (1H, dd, $J = 3.6$, 8.8 Hz, H-6′), 6.88 (1H, td, $J = 17.2$, 7.2 Hz, H-4′), 6.85 (1H, td, $J = 3.2$, 8.4 Hz, H-3), 6.71 (1H, td, $J = 3.6$, 8.8 Hz, H-5′), 6.66 (1H, dd, $J = 3.2$, 8.4 Hz, H-3′), 5.81 (1H, d, $J = 17.2$ Hz, H-2), 4.21(2H, m, OCH_2), 3.72 (3H, s, OCH_3), 2.52 (2H, t, $J = 6.8$ Hz, H-11), 1.89 (2H, t, $J = 6.8$ Hz, H-4), 1.66–1.61 (2H, m, H-10), 1.34–1.32 (2H, m, H-5), 1.30 (3H, t, $J = 6.8$ Hz, $OCH_2\underline{CH_3}$), 1.28–1.21(8H, m, H-6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 166.1 (C-1), 162.1 (C-2′), 147.6 (C-3), 129.8 (C-6′), 127.6 (C-4′), 126.1 (C-1′), 122.6 (C-5′), 119.6 (C-2), 114.8 (C-3′), 59.2 (OCH_2), 56.4 (OCH_3), 32.8 (C-4, 10), 30.5 (C-6, 7), 30.3 (C-8), 30.0 (C-5), 29.8 (C-9), 25.6 (C-11); LC-MS: *m/z* 319.3 $(M + H)^+$, 341.3 $(M + Na)^+$.

*11-(2-Methoxyphenyl)-undec-2-enoic acid (**12**)*

A solution of 11-(2-methoxy-Phenyl)-undec-2-enoic acid ethyl ester (**11**, 2 g, 0.006289 mol) in methanol (10 mL) was treated with 8 N KOH solution (5 mL) slowly and drop wise for 10 min. Then, the reaction mixture was stirred at room temperature for 1 h. After completion of reaction, the reaction mixture was poured into water (50 mL), acidified with 2N HCl and extracted with ethyl acetate (2 × 200 mL). The organic layer was washed with brine solution, dried over Na_2SO_4 and concentrated. The residue was purified by column chromatography on silica gel (10 % ethyl acetate/hexane) to obtain 11-(2-methoxy Phenyl)-undec-2-enoic acid (**12**, 1.51 g, 82 %). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 11.2 (1H, s, OH), 7.16 (1H, t, $J = 17.2$ Hz, H-3), 7.04 (1H, dd, $J = 3.2$, 7.6 Hz, H-6′), 6.97 (1H, td, $J = 8.0$, 3.6 Hz, H-4′), 6.79 (1H, td, $J = 8.4$, 3.6 Hz, H-5′), 6.74 (1H, dd, $J = 7.6$, 3.2 Hz, H-3′), 6.02 (1H, d, $J = 17.2$ Hz, H-2), 3.72 (3H, s, OCH_3), 2.52 (2H, t, $J = 7.2$ Hz, H-11), 1.93 (2H, t, $J = 7.2$ Hz, H-4), 1.66–1.64 (2H, m, H-10), 1.36–1.32 (2H, m, H-5), 1.29–1.23 (8H, m, H-6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 171.2 (C-1), 159.2 (C-2′), 154.6 (C-3), 129.3 (C-6′), 127.2 (C-4′), 125.2 (C-1′), 120.9 (C-5′), 120.1 (C-2), 116.1 (C-3′), 33.2 (C-4,10), 31.8 (C-6,7,8), 29.8 (C-5), 29.7 (C-9), 26.2 (C-11); LC-MS: *m/z* 305.4 $(M-H)^-$.

*11-(2-Methoxyphenyl)-1-(2,4,6-trimethoxyphenyl)-undec-2-en-1-one (**13**)*

A mixture of 11-(2- methoxyphenyl)-undec-2-enoic acid (**12**, 600 mg, 2.089 mmol) and thionyl chloride (0.5 mL, 4.137 mmol) was refluxed for 1 h. Then, excess of thionyl chloride was removed by heating under high vacuum to obtain the acid chloride. A mixture of aluminum chloride (340 mg, 2.55 mmol) and dichloromethane (5 mL) was cooled to 0-5 °C, and then treated with a solution of trimethoxyphloroglucinol in methylenedichloride (5 mL) drop wise. After completion of addition, the reaction mixture was stirred for 30 min, and then treated drop wise with a solution of previously prepared dried acid chloride in MDC (10 mL) for 20 min. After completion of addition, the reaction mixture was stirred for 3 h at 20 °C. After completion of reaction, the reaction mixture was poured into water (50 mL), extracted with ethyl acetate (2 × 250 mL) and the combined organic layer was washed with brine solution, dried over Na_2SO_4 and concentrated under vacuum. The crude residue was purified by column chromatography on silica gel (10% ethyl acetate/hexane) to obtain 11-(2-methoxyphenyl)-1-(2,4,6-trimethoxyphenyl)-undec-2en-1-one (**13**, 580 mg, 65 %). ^{1}H NMR ($CDCl_3$, 400 MHz): δ

7.15 (1H, td, $J = 7.6$, 2.4 Hz, H-4′), 7.12 (1H, dd, $J = 8.0$, 2.4 Hz, H-6′), 6.99 (1H, d, $J = 17.2$ Hz, H-2), 6.96 (1H, td, $J = 7.6$,17.2 Hz, H-3), 6.86 (1H, t, $J = 7.6$ Hz, H-5′), 6.82 (1H, d, $J = 8.0$ Hz, H-3′), 6.08 (2H, s, H-3″, 5″), 3.85 (9H, s, OCH_3), 3.73 (3H, s, OCH_3), 2.52 (2H, t, $J = 7.6$ Hz, H-11), 1.89 (2H, t, $J = 7.6$ Hz, H-4), 1.66–1.62 (2H, m, H-10), 1.35–1.33 (2H, m, H-5), 1.29–1.22 (8H, m,H-6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 188.2 (C-1), 162.8 (C-2″, 6″), 161.3 (C-4″), 156.5 (C-2′), 147.6 (C-3), 129.4 (C-6′), 126.7 (C-4′), 125.3 (C-2), 125.1 (C-1′), 118.7 (C-5′), 113.9 (C-3′), 103.6 (C-1″), 94.3 (C-3″, 5″), 58.4 (OCH_3), 56.1 (OCH_3), 32.8 (C-11), 32.6 (C-4), 30.4 (C-10), 30.3 (C-5), 30.0 (C-9), 29.9 (C-6), 25.8 (C-7, 8); LC-MS: *m/z* 457.3 $(M + H)^+$, 479.3 $(M + Na)^+$.

*11-(2-Methoxyphenyl)-1-(2,4,6-trimethoxyphenyl)-undecan-1-one (**14**)*

A mixture of 11-(2-methoxyphenyl)-1-(2,4,6-trimethoxyphenyl)-undec-2-en-1-one (**13**, 400 mg, 0.909 mmol), ethyl acetate (20 mL) and catalytic amount of 10% palladium on $CaCO_3$ reagent was stirred under H_2 atmosphere for 3 h at rt. After completion of reaction, the reaction mixture was filtered on celite, washed the celite bed with ethyl acetate (100 mL) and the filtrate was concentrated under vacuum. The residue was purified by column chromatography on silica gel (5% ethyl acetate/hexane) to get 11-(2-methoxyphenyl)-1-(2,4,6-trimethoxyphenyl)-undecan-1-one (**14**, 333 mg, 83%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.16 (1H, td, $J = 7.6$, 2.0 Hz, H-4′), 7.12 (1H, dd, $J = 8.0$, 2.0 Hz, H-6′), 6.86 (1H, t, $J = 7.6$ Hz, H-5′), 6.83 (1H, d, $J = 8.0$ Hz, H-3′), 6.09 (2H, s, H-3″, 5″), 3.81 (6H, s, OCH_3), 3.76 (6H, s, OCH_3), 2.71 (2H, t, $J = 7.6$ Hz, H-2), 2.59 (2H, t, $J = 8.0$ Hz, H-11), 1.65–1.59 (2H, m, H-3), 1.55–1.53 (2H, m, H-10), 1.30 (12H, s, H-4, 5, 6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 204.2 (C-1), 162.1 (C-2″, 6″), 158.1 (C-4″), 157.5 (C-2′), 131.5 (C-6′), 129.7 (C-4′), 126.2 (C-1′), 120.3 (C-5′), 114.2 (C-3′), 110.4 (C-1″), 90.8 (C-3″, 5′′), 55.8 (OCH_3), 55.4 (OCH_3), 55.3 (OCH_3), 45.0 (C-11), 30.1 (C-4), 29.9 (C-10), 29.7 (C-5), 29.6 (C-9), 29.5 (C-6), 23.9 (C-7, 8); LC-MS: *m/z* 459.3 $(M + H)^+$, 481.3 $(M + Na)^+$.

*11-(2-Hydroxyphenyl)-1-(2,4,6-trihydroxylphenyl)-undecan-1-one (**15**)*

A mixture of 11-(2-methoxyphenyl)-1-(2,4,6-trimethoxyphenyl)-undecan-1-one (**14**, 910 mg, 2.058 mmol), freshly prepared pyridinium chloride (3 g, 26.08 mmol) was heated at 170–180 °C for 1 h. After completion of reaction, which was monitored by TLC (chloroform: acetone [7:3]), the reaction mixture was poured into water (100 mL), extracted with ethyl acetate (3 × 300 mL). The organic layer was washed with brine solution, dried over Na_2SO_4 and concentrated under vacuum. The residue was purified by column chromatography on silica gel (30–40% ethyl acetate/hexane) to get 11-(2-hydroxyphenyl)-1-(2,4,6-trihydroxylphenyl)-undecan-1-one (**15**, 268 mg, 35%). mp 58–60 °C; ^{1}H NMR (d_6-DMSO, 400 MHz): δ 12.21 (2H, s, OH), 10.29 (1H, s, OH), 9.11 (1H, s, OH), 7.01 (1H, d, $J = 7.6$ Hz, H-6′), 6.96 (1H, t, $J = 7.6$ Hz, H-4′), 6.75 (1H, d, $J = 7.6$ Hz, H-3′), 6.68 (1H, t, $J = 7.6$ Hz, H-5′), 5.79 (2H, d, $J = 0.8$ Hz, H-3″, 5″), 2.96 (2H, t, $J = 7.2$ Hz, H-2), 2.47 (2H, t, $J = 7.2$ Hz, H-11), 1.58–1.48 (6H, m, H-3, 4, 10), 1.27 (10H, m, H-5, 6, 7, 8, 9); ^{13}C NMR (d_6-DMSO, 100 MHz): δ 205.2 (C-1), 164.4 (C-4″), 164.1 (C-2″, 6″), 154.9 (C-2′), 129.6 (C-6′), 128.5 (C-4′), 126.4 (C-1′), 118.7 (C-5′), 114.8 (C-3′), 103.8 (C-1″), 94.9 (C-3″, 5″), 43.0 (C-2), 29.5 (C-10), 29.3 (C-9), 29.0 (C-8), 28.9 (C-4, 5, 6, 7), 24.4 (C-3, 11); LC-MS: *m/z* 385.2 $(M-H)^-$; Q-Tof: *m/z* 387.2168 $(M + H)^+$ (387.2171 calculated for $C_{23}H_{31}O_5$).

*General procedure for 11-(substituted phenyl)-1-(substituted phenyl)-undec-2-en-1-one (**17a–p**)*

A mixture of suitable 9-(substituted phenyl)-nonan-1-al (**10b–e**, 0.0016 mol) and 1-(substituted phenyl)-2-(triphenylphosphonyllidiene)-ethanone (**16a–d**, 0.0016 mol) and dry THF (20 mL) was refluxed for 4 h. After completion of reaction, the reaction mixture was concentrated under vacuum. The crude residue was purified by column chromatography on silica gel (5% ethyl acetate/hexane) to get the corresponding 11-(substituted phenyl)-1-(substituted phenyl)-undec-2en-1-one compound (**17a–p**) with yields in the range of 45–53%.

11-(3,4,5-Trimethoxyphenyl)-1-(phenyl)-undec-2-en-1-one (**17a**) Solid (300 mg, 47%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.85 (2H, d, $J = 7.6$ Hz, H-2″, 6″), 7.52 (1H, t, $J = 7.2$ Hz, H-4″), 7.43 (2H, t, $J = 7.6$ Hz, H-3″, 5″), 6.98 (1H, t, $J =$ 16.4, 7.2 Hz, H-2), 6.97 (1H, d, $J = 16.4$ Hz, H-3), 6.08 (2H, s, H-2′, 6′), 3.72 (9H, s, OCH_3), 2.55 (2H, t, $J = 7.2$ Hz, H-11), 1.96 (2H, t, $J = 6.8$ Hz, H-4), 1.62–1.59, (2H, m, H-10), 1.35–1.31 (2H, m, H-5), 1.26–1.22 (8H, m, H-6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 189.8 (C-1), 150.7 (C-3′, 5′), 149.6 (C-3), 137.2 (C-1″), 136.4 (C-4″), 134.0 (C-1′), 133.6 (C-4′), 131.9 (C-2″, 6″), 129.8 (C-3″, 5″), 129.3 (C-2), 105.4 (C-2′, 6′), 58.4 (OCH_3), 58.2 (OCH_3), 36.2 (C-11), 33.6 (C-4), 31.3 (C-10), 29.7 (C-6, 7), 29.6 (C-8), 29.3 (C-5), 29.1 (C-9); LC-MS: *m/z* 411.3 $(M + H)^+$, 433.4 $(M + Na)^+$, 449.2 $(M + K)^+$.

11-(3,4-Dimethoxyphenyl)-1-(phenyl)-undec-2-en-1-one (**17b**) Solid (315 mg, 52%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.85 (2H, d, $J = 7.2$ Hz, H-2″, 6″), 7.51 (1H, t, $J = 7.2$ Hz, H-4″), 7.43 (2H, t, $J = 7.6$ Hz, H-3″, 5″), 6.98 (1H, td, $J =$

6.8, 16.4 Hz, H-3), 6.97 (1H, d, $J = 16.8$ Hz, H-2), 6.61 (1H, dd, $J = 8.0$, 3.6 Hz, H-5′), 6.59 (1H, d, $J = 3.6$ Hz, H-6′), 6.51 (1H, d, $J = 8.4$ Hz, H-2′), 3.64 (6H, s, OCH_3), 2.56 (2H, t, $J = 7.2$ Hz, H-11), 1.96 (2H, t, $J = 7.2$ Hz, H-4), 1.61–1.59 (2H, m, H-10), 1.35–1.32 (2H, m, H-5), 1.28–1.22 (8H, m, H-6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 189.8 (C-1), 149.7 (C-3), 149.6 (C-3′), 147.6 (C-4′), 137.6 (C-1′), 134.9 (C-4″), 132.1 (C-1′), 131.8 (C-2′, 6″), 129.6 (C-3″, 5″), 129.3 (C-2), 121.5 (C-6′), 115.2 (C-2′), 113.6 (C-5′), 58.5 (OCH_3), 36.3 (C-11), 33.2 (C-4), 31.3 (C-10), 29.8 (C-6, 7), 29.7 (C-8), 29.6 (C-5), 29.3 (C-9); LC-MS: *m/z* 381.3 $(M + H)^+$, 403.4 $(M + Na)^+$.

11-(4-Methoxyphenyl)-1-(phenyl)-undec-2-en-1-one (**17c**) Solid (280 mg, 50%); ^{1}H NMR (d_6-DMSO, 400 MHz): δ 7.95 (2H, t, $J = 7.6$ Hz, H-2″, 6″), 7.51 (1H, t, $J = 7.6$ Hz, H-4″), 7.45 (2H, t, $J = 7.6$ Hz, H-3″, 5″), 7.08 (2H, d, $J = 8.0$ Hz, H-2′, 6′), 6.98 (1H, td, $J = 7.6$, 16.4 Hz, H-3), 6.97 (1H, d, $J = 16.4$ Hz, H-2), 6.81 (2H, d, $J = 8.0$ Hz, H-3′, 5′), 3.78 (3H, s, OCH_3), 2.53 (2H, t, $J = 6.8$ Hz, H-11), 1.95 (2H, t, $J = 7.2$ Hz, H-4), 1.66–1.62 (2H, m, H-10), 1.38–1.34 (2H, m, H-5), 1.29–1.21 (8H, m, H-6, 7, 8, 9); ^{13}C NMR (d_6-DMSO, 100 MHz): δ 189.8 (C-1), 157.6 (C-4′), 149.7 (C-3), 137.8 (C-1″), 134.6 (C-4″), 131.2 (C-1″), 129.8 (C-2″, 6″), 129.3 (C-2′), 129.2 (C-2′), 114.2 (C-3′, 5′), 55.9 (OCH_3), 36.0 (C-11), 33.3 (C-4), 31.2 (C-10), 30.6 (C-6, 7), 29.8 (C-8), 29.7 (C-5), 29.3 (C-9); LC-MS: *m/z* 351.3 $(M + H)^+$.

11-(phenyl)-1-(phenyl)-undec-2-en-1-one (**17d**) Oily compound, (270 mg, 53%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.82 (2H, d, $J = 7.2$ Hz, H-2″, 6″), 7.54 (1H, t, $J = 7.6$ Hz, H-4″), 7.42 (2H, t, $J = 7.2$ Hz, H-3″, 5″), 7.21 (2H, t, $J = 8.8$ Hz, H-3′, 5′), 7.12 (2H, d, $J = 7.6$ Hz, H-2′, 6′), 7.10 (1H, t, $J = 7.6$ Hz, H-4′), 6.98 (1H, td, $J = 7.2$, 16.8 Hz, H-3), 6.97 (1H, d, $J = 16.8$ Hz, H-2), 2.55 (2H, t, $J = 6.8$ Hz, H-11), 1.92 (2H, t, $J = 7.2$ Hz, H-4), 1.66–1.61 (2H, m, H-10), 1.38–1.33 (2H, m, H-5), 1.29–1.22 (8H, m, H-6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 189.8 (C-1), 149.8 (C-3), 138.9 (C-1′), 137.9 (C-1″), 134.5 (C-4″), 131.6 (C-2″, 6′′), 129.8 (C-3″, 5″), 129.2 (C-2′, 6′), 128.6 (C-3′, 5′), 128.2 (C-4′), 126.0 (C-2), 36.2 (C-11), 33.2 (C-4), 31.2 (C-10), 30.6 (C-6, 7), 29.8 (C-8), 29.7 (C-5), 29.3 (C-9); LC-MS: *m/z* 321.3 $(M + H)^+$, 343.4 $(M + Na)^+$.

11-(3,4,5-Trimethoxyphenyl)-1-(2-hydroxy-4-methoxyphenyl)-undec-2-en-1-one (**17e**) Solid (340 mg, 47%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.53 (1H, d, $J = 8.4$ Hz, H-6″), 6.98 (1H, td, $J = 7.2$, 16.8 Hz, H-3), 6.97 (1H, d, $J = 16.8$ Hz, H-2), 6.52–6.47 (2H, m, H-3″, 5″), 6.08 (2H, s, H-2′, 6′), 3.86 (3H, s, OCH_3), 3.84 (9H, s OCH_3), 2.55 (2H, t, $J = 6.8$ Hz, H-11), 1.94 (2H, t, $J = 7.6$ Hz, H-4), 1.63–1.60 (2H, m, H-10), 1.33–1.29 (2H, m, H-5), 1.26–1.22 (8H, m, H-6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 189.8 (C-1), 167.8 (C-4″), 162.9 (C-2″), 150.7 (C-3′, 5′), 149.6 (C-3), 136.0 (C-1′), 133.3 (C-6″), 132.5 (C-4′), 131.2 (C-2), 115.1 (C-1″), 107.6 (C-2′, 6′), 106.5 (C-5″), 103.2 (C-3″), 36.3 (C-11), 33.2 (C-4), 31.6 (C-10), 29.8 (C-6,7), 29.7 (C-8), 29.4 (C-5), 29.1 (C-9); LC-MS: *m/z* 457.2 $(M + H)^+$, 479.4 $(M + Na)^+$.

11-(3,4-Dimethoxyphenyl)-1-(2-hydroxy-4-methoxyphenyl)-undec-2-en-1-one (**17f**) Solid (300 mg, 45%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.51(1H, d, $J = 9.2$ Hz, H-6″), 6.98 (1H, td, $J = 7.2$, 16.8 Hz, H-3), 6.97 (1H, d, $J = 16.8$ Hz, H-2), 6.72 (1H, d, $J = 8.8$ Hz, H-5′), 6.69–6.65 (2H, m, H-2′, 6′), 6.46–6.41 (2H, m, H-3″, 5″), 5.08 (1H, s, OH), 3.71 (3H, s, OCH_3), 2.55 (2H, t, $J = 7.6$ Hz, H-11), 1.93 (2H, t, $J = 7.2$ Hz, H-4), 1.69–1.62 (2H, m, H-10), 1.35–1.32 (2H, m, H-5), 1.26–1.21 (8H, m, H-6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 189.8 (C-1), 167.9 (C-4″), 162.6 (C-2″), 150.1 (C-3), 149.7 (C-3′), 147.8 (C-4′), 132.2 (C-1′), 132.1 (C-6″), 131.8 (C-2), 121.6 (C-6′), 115.3 (C-1′′), 114.9 (C-2′), 113.2 (C-5′), 108.2 (C-5″), 103.2 (C-3″), 36.4 (C-11), 33.3 (C-4), 31.2 (C-10), 30.8 (C-6, 7), 29.8 (C-8), 29.7 (C-5), 29.3 (C-9); LC-MS: *m/z* 427.3 $(M + H)^+$, 333.4 $(M + Na)^+$.

11-(4-Methoxyphenyl)-1-(2-hydroxy-4-methoxyphenyl)-undec-2-en-1-one (**17g**) Solid (310 mg, 49%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.62 (1H, d, $J = 9.6$ Hz, H-6″), 7.02 (2H, d, $J = 8.4$ Hz, H-2′, 6′), 6.98 (1H, td, $J = 7.2$, 16.8 Hz, H-3), 6.97 (1H, d, $J = 16.8$ Hz, H-2), 6.86 (2H, d, $J = 8.4$ Hz, H-3′, 5′), 6.42–6.39 (2H, m, H-3″, 5″), 3.81 (3H, s, OCH_3), 3.78 (3H, s, OCH_3), 2.55 (2H, t, $J = 7.6$ Hz, H-11), 1.91 (2H, t, $J = 7.6$ Hz, H-4), 1.69–1.65 (2H, m, H-10), 1.33–1.30 (2H, m, H-5), 1.27–1.22 (8H, m, H-6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 189.8 (C-1), 167.8 (C-4″), 162.8 (C-2″), 157.9 (C-4′), 149.5 (C-3), 132.0 (C-6″), 131.3 (C-1′), 129.5 (C-2′, 6′), 126.1 (C-2), 115.2 (C-1″), 114.8 (C-3′, 5′), 108.5 (C-5″), 103.5 (C-3″), 36.2 (C-11), 33.1 (C-4), 31.2 (C-10), 30.8 (C-6, 7), 29.8 (C-8), 29.7 (C-5), 29.3 (C-9); LC-MS: *m/z* 397.3 $(M + H)^+$, 419.4 $(M + Na)^+$.

11-(Phenyl)-1-(2-hydroxy-4-methoxyphenyl)-undec-2-en-1-one (**17h**) Solid (300 mg, 52%); ^{1}H NMR (d_6-DMSO, 400 MHz): δ 7.62 (1H, d, $J = 9.6$ Hz, H-6″), 7.21 (2H, t, $J = 7.6$ Hz, H-3′, 5′), 7.16 (2H, d, $J = 7.2$ Hz, H-2′, 6′), 7.11 (1H, d, $J = 7.2$ Hz, H-4′), 6.98 (1H, td, $J = 7.2$, 16.8 Hz, H-3), 6.97 (1H, d, $J = 16.8$ Hz, H-2), 6.41 (1H, dd, $J = 7.2$, 2.4 Hz, H-5″), 6.39 (1H, d, $J = 2.4$ Hz, H-3″), 5.01 (1H, s, OH), 3.71 (3H, s, OCH_3), 2.55 (2H, t, $J = 7.2$ Hz, H-11), 1.92 (2H, t, $J = 7.2$ Hz, H-4), 1.68–1.62 (2H, m, H-10), 1.39–1.35 (2H, m, H-5), 1.28–1.22 (8H, m, H-6, 7, 8, 9); ^{13}C NMR (d_6-DMSO, 100 MHz): δ 189.8 (C-1), 167.9 (C-4″), 162.9 (C-2″), 149.7 (C-3), 138.9 (C-1′), 132.9 (C-6″),

129.8 (C-2′, 3′, 4′, 5′), 129.6 (C-4′), 126.8 (C-2), 116.1 (C-1″), 108.4 (C-5″), 103.5 (C-3″), 36.2 (C-11), 33.3 (C-4), 31.2 (C-10), 30.8 (C-6, 7), 29.8 (C-8), 29.7 (C-5), 29.3 (C-9); LC-MS: *m/z* 365.3 $(M-H)^-$.

11-(3,4,5-Trimethoxyphenyl)-1-(3,4-dimethoxyphenyl)-undec-2-en-1-one (**17i**) Oily compound, (370 mg, 49%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.68 (1H, dd, $J = 1.6$,8 Hz, H-6″), 7.54 (1H, d, $J = 1.6$ Hz, H-2″), 6.98 (1H, td, $J = 6.8$, 17.2 Hz, H-3), 6.97 (1H, d, $J = 17.2$ Hz, H-2), 6.88 (1H, d, $J = 8.4$ Hz, H-5″), 6.19 (2H, s, H-2′, 6′), 3.94 (3H, s, OCH_3), 3.93 (3H, s, OCH_3), 3.84 (3H, s, OCH_3), 3.82 (6H, s, OCH_3), 2.62 (2H, t, $J = 7.6$ Hz, H-11), 2.11 (2H, t, $J = 8.0$ Hz, H-4), 1.69–1.63 (2H, m, H-10), 1.60–1.57 (2H, m, H-5), 1.33–1.27 (8H, m, H-6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100MHz): δ 199.2 (C-1), 156.2 (C-4″), 152.1 (C-3′, 5′), 149.7 (C-3″), 147.9 (C-3), 136.7 (C-1′), 136.2 (C-4′), 131.7 (C-1″), 123.8 (C-2), 122.1 (C-6″), 111.6 (C-2″), 110.1 (C-5″), 103.3 (C-2′, 6′), 56.9 (OCH_3), 56.6 (OCH_3), 56.4 (OCH_3), 56.1 (OCH_3), 38.6 (C-11), 36.3 (C-4), 31.5 (C-10), 29.6 (C-6, 7), 29.4 (C-8), 29.2 (C-5), 29.1 (C-9); LC-MS: *m/z* 471.4 (M + H) +, 493.4 $(M + Na)^+$, 508.3 $(M + k)^+$.

11-(3, 4-Dimethoxyphenyl)-1-(3,4-dimethoxyphenyl)-undec-2-en-1-one (**17j**) White solid (370 mg 52 %); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.24 (1H, d, $J = 3.2$ Hz, H-6″), 6.98 (1H, td, $J = 7.2$, 16.8 Hz, H-3), 6.97 (1H, d, $J = 16.8$ Hz, H-2), 6.96 (1H, dd, $J = 3.3$, 8.4 Hz, H-5″), 6.82 (1H, d, $J = 8.8$ Hz, H-5″), 6.76 (1H, d, $J = 8.4$ Hz, H-5′), 6.71–6.68 (2H, m, H-2′, 6′), 3.72 (6H, s, OCH_3), 3.69 (6H, s, OCH_3), 2.55 (2H, t, $J = 7.6$ Hz, H-11), 1.92 (2H, t, $J = 7.2$ Hz, H-4), 1.69–1.63 (2H, m, H-10), 1.36–1.34 (2H, m, H-5), 1.28–1.23 (8H, m, H-6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 189.8 (C-1), 155.2 (C-4″), 151.9 (C-3″), 149.6 (C-3), 149.3 (C-3′), 147.9 (C-4′), 132.3 (C-1′), 132.0 (C-1″), 131.8 (C-2), 123.4 (C-6″), 121.8 (C-6′), 116.8 (C-2″), 115.6 (C-5″), 114.2 (C-2′, 5′), 58.2 (OCH_3), 36.3 (C-11), 33.2 (C-4), 31.3 (C-10), 29.8 (C-6, 7), 29.7 (C-8), 29.3 (C-5), 29.1 (C-9); LC-MS: *m/z* 341.3 $(M + H)^+$, 363.4 $(M + Na)^+$.

11-(4-Methoxyphenyl)-1-(3,4-dimethoxyphenyl)-undec-2-en-1-one (**17k**) Solid (300 mg, 46%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.68 (1H, dd, $J = 1.6$, 8.4 Hz, H-6″), 7.55 (1H, d, $J = 1.6$ Hz, H-2″), 7.09 (2H, d, $J = 8.4$ Hz, H-2′, 6′), 6.98 (1H, td, $J = 7.2$, 16.8 Hz, H-3), 6.92 (1H, d, $J = 16.8$ Hz, H-2), 6.86 (1H, d, $J = 8.4$ Hz, H-5″), 6.83 (2H, d, $J = 8.8$ Hz, H-3′, 5′), 3.72 (9H, s, OCH_3), 2.55 (2H, t, $J = 7.2$ Hz, H-11), 1.93 (2H, t, $J = 7.2$ Hz, H-4), 1.69–1.63 (2H, m, H-10), 1.36–1.31 (2H, m, H-5), 1.28–1.22 (8H, m, H-6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 189.8 (C-1), 157.6 (C-4′), 156.5 (C-4″), 151.3 (C-3″), 149.7 (C-3), 132.8 (C-1′), 131.2 (C-1″), 129.6 (C-2′, 6′), 125.7 (C-2), 122.9 (C-6″), 116.1 (C-2″), 115.8 (C-5″), 115.1 (C-3′, 5′), 56.4 (OCH_3), 36.2 (C-11), 33.2 (C-4), 31.3 (C-10), 29.8 (C-6, 7), 29.7 (C-8), 29.2 (C-5), 29.3 (C-9); LC-MS: *m/z* 411.3 $(M + H)^+$, 433.4 $(M + Na)^+$.

11-(Phenyl)-1-(3,4-dimethoxyphenyl)-undec-2-en-1-one (**17l**) White solid (290 mg, 48 %); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.56 (1H, dd, $J = 1.6$, 8.4 Hz, H-6″), 7.51 (1H, d, $J = 1.6$ Hz, H-2″), 7.24 (2H, t, $J = 8.0$ Hz, H-3′, 5′), 7.12 (2H, d, $J = 7.2$ Hz, H-2′, 6′), 7.06 (1H, t, $J = 7.2$ Hz, H-4′), 6.98 (1H, td, $J = 7.2$, 16.8 Hz, H-3), 6.94 (1H, d, $J = 16.8$ Hz, H-2), 6.81 (1H, d, $J = 8.4$ Hz, H-5″), 3.73 (6H, s, OCH_3), 2.55 (2H, t, $J = 7.6$ Hz, H-11), 1.93 (2H, t, $J = 7.2$ Hz, H-4), 1.68–1.62 (2H, m, H-10), 1.36–1.33 (2 H, m, H-5), 1.29–1.25 (8H, m, H-6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 189.8 (C-1), 156.8 (C-4″), 151.3 (C-3″), 150.7 (C-3), 138.7 (C-1′), 132.2 (C-1″), 131.0 (C-2′, 6′), 128.7 (C-3′, 5′), 128.3 (C-4′), 126.2 (C-2), 123.5 (C-6″), 116.1 (C-2″), 115.8 (C-5″), 36.3 (C-11), 33.2 (C-4), 31.3 (C-10), 29.8 (C-6, 7), 29.7 (C-8), 29.3 (C-5), 29.1 (C-9); LC-MS: *m/z* 381.3 $(M + H)^+$, 403.4 $(M + Na)^+$, 419.3 $(M + K)^+$.

11-(3,4,5-Trimethoxyphenyl)-1-(2,5-dimethoxyphenyl)-undec-2-en-1-one (**17m**) Oily compound, (390 mg, 50%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.21 (1H, d, $J = 3.2$ Hz, H-6″), 7.02 (1H, dd, $J = 3.2$, 8.8 Hz, H-4″), 6.98 (1H, td, $J =$ 7.2, 16.8 Hz, H-3), 6.97 (1H, d, $J = 16.8$ Hz, H-2), 6.88 (1H, d, $J = 8.4$ Hz, H-3″), 6.12 (2H, s, H-2′, 6′), 3.86 (9H, s, OCH_3), 3.83 (3H, s, OCH_3), 3.78 (3H, s, OCH_3), 2.55 (2H, t, $J = 7.2$ Hz, H-11), 1.94 (2H, t, $J = 7.2$ Hz, H-4), 1.66–1.62 (2H, m, H-10), 1.39–1.36 (2H, m, H-5), 1.29–1.22 (8H, m, H-6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 189.8 (C-1), 153.6 (C-2″), 150.6 (C-5″), 149.8 (C-3′, 5′), 146.1 (C-3), 137.2 (C-1′), 134.2 (C-4′), 133.0 (C-2), 122.2 (C-1″), 121.9 (C-4″), 116.8 (C-6″), 115.8 (C-3″), 106.5 (C-2′, 6′), 36.4 (C-11), 33.3 (C-4), 31.2 (C-10), 30.4 (C-6, 7), 29.8 (C-8), 29.7 (C-5), 29.3 (C-9); LC-MS: *m/z* 471.3 $(M + H)^+$, 493.4 $(M + Na)^+$.

11-(3,4-Dimethoxyphenyl)-1-(2,5-dimethoxyphenyl)-undec-2-en-1-one (**17n**) White solid (350 mg, 50%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.52 (1H, dd, $J = 1.6$, 8.4 Hz, H-6″), 7.51 (1H, d, $J = 1.6$ Hz, H-4″), 6.98 (1H, td, $J = 7.2$, 16.8 Hz, H-3), 6.97 (1H, d, $J = 16.8$ Hz, H-2), 6.89 (1H, d, $J = 8.4$ Hz, H-3″), 6.68 (1H, d, $J = 7.6$ Hz, H-5′), 6.64 (2H, m, H-2′, 6′), 3.74 (6H, s, OCH_3), 3.69 (6H, s, OCH_3), 2.55 (2H, t, $J = 7.3$ Hz, H-11), 1.92 (2H, t, $J = 7.2$ Hz, H-4), 1.66–1.64 (2H, m, H-10), 1.32–1.30 (2H, m, H-5), 1.28–1.22 (8H, m, H-6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 189.8 (C-1), 155.8 (C-5″), 153.5 (C-2″), 149.6 (C-3), 149.4 (C-3′), 147.0 (C-4′), 132.2 (C-1′), 131.9 (C-2), 122.2 (C-1″), 121.8 (C-6′), 121.6 (C-4″), 116.8 (C-6″), 115.8 (C-3″), 114.2 (C-2′, 5′), 36.3 (C-11), 33.2 (C-4), 31.3

(C-10), 30.6 (C-6, 7), 29.8 (C-8), 29.6 (C-5), 29.3 (C-9); LC-MS: *m/z* 441.3 $(M + H)^+$, 463.4 $(M + Na)^+$, 479.2 $(M + K)^+$.

11-(4-Methoxyphenyl)-1-(2,5-dimethoxyphenyl)-undec-2-en-1-one (**17o**) White solid (330 mg, 51%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.22 (1H, d, $J = 3.2$ Hz, H-6″), 7.06 (2H, d, $J = 8.8$ Hz, H-2′, 6′), 6.98 (1H, td, $J = 7.2$, 16.8 Hz, H-3), 6.97 (1H, d, $J = 16.8$ Hz, H-2), 6.92 (1H, dd, $J = 3.2$, 8.8 Hz, H-4″), 6.86 (1H, d, $J = 8.8$ Hz, H-3″), 6.81 (2H, d, $J = 8.8$ Hz, H-3′, 5′), 3.82 (2H, s, OCH_3), 3.81 (3H, s, OCH_3), 3.78 (3H, s, OCH_3), 2.55 (2H, t, $J = 7.2$ Hz, H-11), 1.94 (2H, t, $J = 7.2$ Hz, H-4), 1.62–159 (2H, m, H-10), 1.37–1.34 (2H, m, H-5), 1.28–1.22 (8H, m, H-6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 189.8 (C-1), 158.8 (C-4′), 153.6 (C-2″), 152.9 (C-5″), 149.8 (C-3), 132.8 (C-1′), 131.2 (C-2′, 6′), 130.1 (C-2), 129.2 (C-1″), 124.2 (C-4″), 116.8 (C-6″), 116.2 (C-3″), 115.2 (C-3′, 5′), 36.3 (C-11), 33.3 (C-4), 31.4 (C-10), 29.8 (C-6, 7), 29.7 (C-8), 29.5 (C-5), 29.3 (C-9); LC-MS: *m/z* 411.3 $(M + H)^+$, 433.4 $(M + Na)^+$.

11-(Phenyl)-1-(2,5-dimethoxyphenyl)-undec-2-en-1-one (**17p**) Oily substance, (285 mg, 47%) ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.24 (2H, t, $J = 8.0$ Hz, H-3′, 5′), 7.20 (1H, d, $J = 3.2$ Hz, H-6″), 7.12 (2H, d, $J = 7.2$ Hz, H-2′, 6′), 7.08 (1H, t, $J = 7.2$ Hz, H-4′), 6.98 (1H, td, $J = 7.2$, 16.8 Hz, H-2), 6.97 (1H, d, $J = 16.8$ Hz, H-3), 6.81 (1H, dd, $J = 2.8$, 8.8 Hz, H-4″), 6.76 (1H, d, $J = 9.2$ Hz, H-3″), 3.73 (6H, s, OCH_3), 2.55 (2H, t, $J = 7.6$ Hz, H-11), 1.94 (2H, t, $J = 7.2$ Hz, H-4), 1.66–1.62 (2H, m, H-10), 1.35–1.32 (2H, m, H-5), 1.28–1.22 (8H, m, H-6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 189.8 (C-1), 154.5 (C-2″), 150.7 (C-5″), 147.9 (C-3), 139.7 (C-1′), 132.2 (C-2′, 3′, 5′, 6′), 129.6 (C-2), 127.0 (C-4′), 126.1 (C-1″), 121.2 (C-4″), 116.8 (C-6″), 116.1 (C-3″), 36.0(C-11), 33.3 (C-4), 31.3 (C-10), 29.8 (C-6, 7), 29.7 (C-8), 29.3 (C-5), 29.2 (C-9); LC-MS: *m/z* 381.3 $(M + H)^+$, 403.4 $(M + Na)^+$, 419.2 $(M + K)^+$.

*General procedure for 11-(substituted phenyl)-1-(substituted phenyl)-undecan-1-one (**18a–p**)*

A mixture of 11-(substituted phenyl)-1-(substituted phenyl)-undec-2-en-1-one (**17a–p**, 1.1 mmol), ethyl acetate (20 mL), catalytic amount of 5 % palladium on $CaCO_3$ was stirred under hydrogen atmosphere for 2 h at room temperature. After completion of reaction, the reaction mixture was filtered on super cell and washed with ethyl acetate. The combined filtrate was concentrated under vacuum and the residue was purified by column chromatography on silica gel (5% ethyl acetate/hexane) to obtain the corresponding 11-(substituted phenyl)-1-(substituted phenyl)-l-undecan-1-one (**18a–p**) with yields in the range of 75–87%.

11-(3,4,5-Trimethoxyphenyl)-1-(phenyl)-undecan-1-one (**18a**) White waxy compound, (370 mg, 82%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.95 (2H, d, $J = 8$ Hz, H-2″, 6″), 7.54 (1H, t, $J = 6.8$ Hz, H-4″), 7.44 (2H, t, $J = 8.0$, H-3″, 5″), 6.39 (2H, s, H-2′, 6′), 3.84 (6H, s, OCH_3), 3.82 (3H, s, OCH_3), 2.95 (2H, t, $J = 7.2$ Hz, H-2), 2.54 (2H, t, $J = 8.0$ Hz, H-11), 1.77–1.69 (2H, m, H-3), 1.63–1.56 (2H, m, H-10), 1.34–1.25 (12H, m, H- 4, 5, 6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 200.5 (C-1), 153.1 (C-3′, 5′), 138.7 (C-1″), 137.2 (C-1′), 136.2 (C-4″), 132.8 (C-4′), 128.6 (C-2′, 6″), 128.1 (C-3″, 5″), 105.5 (C-2′, 6′), 60.8 (OCH_3), 56.1 (OCH_3), 38.6 (C-2), 36.4 (C-11), 31.6 (C-10), 29.6 (C-6, 7, 8), 29.5 (C-5), 29.4 (C-4, 9), 24.4 (C-3); LC-MS: *m/z* 413.4 $(M + H)^+$, 435.4 $(M + Na)^+$, 451.3 $(M + K)^+$; Q-Tof: *m/z* 413.2697 $(M + H)^+$ (413.2692 calculated for $C_{26}H_{37}O_4$).

11-(3,4-Dimethoxyphenyl)-1-(phenyl)-undecan-1-one (**18b**) White solid (365 mg, 87%); mp 44–46 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.95 (2H, d, $J = 7.2$ Hz, H-2″, 6″), 7.55 (1H, t, $J = 7.2$ Hz, H-4″), 7.45 (2H, t, $J = 7.2$ Hz, H-3″, 5″), 6.78 (1H, d, $J = 8.8$ Hz, H-5′), 6.72–6.70 (2H, m, H-2′, 6′), 3.87 (3H, s, OCH_3), 3.85 (3H, s, OCH_3), 2.96 (2H, t, $J = 7.6$ Hz, H-2), 2.54 (2H, t, $J = 7.6$ Hz, H-11), 1.76–1.69 (2H, m, H-10), 1.59–1.54 (2H, m, H-3), 1.29 (12H, brs, H-4, 5, 6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 200.5 (C-1), 148.8 (C-3′), 147.1 (C-4′), 137.2 (C-1″), 135.7 (C-4″), 132.8 (C-1′), 128.5 (C-2″, 6″), 128.0 (C-3″, 5″), 120.2 (C-6′), 111.9 (C-2′), 111.5 (C-5′), 55.9 (OCH_3), 55.8 (OCH_3), 38.6 (C-2), 35.6 (C-11), 31.6 (C-10), 29.5 (C-6, 7, 8), 29.4 (C-5), 29.3 (C-9), 29.2 (C-4), 24.4 (C-3); LC-MS: *m/z* 383.4 $(M + H)^+$, 405.4 $(M + Na)^+$, 421.3 $(M + K)^+$; Q-Tof: *m/z* 383.2593 $(M + H)^+$ (383.2586 calculated for $C_{25}H_{35}O_3$).

11-(4-Methoxyphenyl)-1-(phenyl)-undecan-1-one (**18c**) white solid (300 mg, 78%); mp 50–52 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.96 (2H, d, $J = 7.6$ Hz, H-2″, 6″), 7.55 (1H, t, $J = 7.6$ Hz, H-4″), 7.45 (2H, t, $J = 7.6$ Hz, H-3″, 5″), 7.08 (2H, d, $J = 8.0$ Hz, H-2′, 6′), 6.81 (2H, d, $J = 8.4$ Hz, H-3′, 5′), 3.78 (3H, s, OCH_3), 2.95 (2H, t, $J = 7.6$ Hz, H-2), 2.53 (2H, t, $J = 8.0$ Hz, H-11), 1.76–1.69 (2H, m, H-10),1.55 (2H, brs, H-3), 1.29 (12H, brs, H-4, 5, 6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 200.6 (C-1), 157.7 (C-4′), 137.3 (C-1″), 135.1 (C-4″), 132.8 (C-1′), 129.3 (C-2′, 6′), 128.6 (C-2″, 6″), 128.1 (C-3″, 5″), 113.7 (C-3′, 5′), 55.3 (OCH_3), 38.7 (C-2), 35.1 (C-11), 31.7 (C-10), 29.5 (C-6, 7, 8), 29.49 (C-5), 29.4 (C-9), 29.2 (C-4), 24.4 (C-3); LC-MS: *m/z* 353.3 $(M + H)^+$, 375.3 $(M + Na)^+$, 391.2 $(M + K)^+$; Q-Tof: *m/z* 353.2489 $(M + H)^+$ (353.2481 calculated for $C_{24}H_{33}O_2$).

11-(Phenyl)-1-(phenyl)-undecan-1-one (**18d**) Oily compound, (270 mg, 76%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.95 (2H, d, $J = 7.2$ Hz, H-2″, 6″), 7.54 (1H, t, $J = 7.2$ Hz, H-4″),

7.44 (2H, t, $J = 7.6$ Hz, H-3″, 5″), 7.26 (2H, t, $J = 8.8$ Hz, H-3′, 5′), 7.17 (2H, d, $J = 7.6$ Hz, H-2′, 6′), 7.15 (1H, t, $J = 7.6$ Hz, H-4′), 2.95 (2H, t, $J = 7.6$ Hz, H-2), 2.59 (2H, t, $J = 8.0$ Hz, H-11), 1.76–1.69 (2H, m, H-10), 1.64–1.56 (2H, m, H-3), 1.38–1.28 (12H, m, H-4, 5, 6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 200.5 (C-1), 142.9 (C-1′), 137.2 (C-1″), 132.8 (C-4″), 128.5 (C-2″, 6″), 128.4 (C-3″, 5″), 128.2 (C-2′, 6′), 128.0 (C-3′, 5′), 125.5 (C-4′), 38.6 (C-2), 35.9 (C-11), 31.9 (C-10), 31.4 (C-6, 7), 29.5 (C-8), 29.4 (C-5), 29.3 (C-9), 29.2 (C-4), 24.4 (C-3); LC-MS: *m/z* 323.3 (M + H) + , 345.3 (M + Na)+; Q-Tof: *m/z* 323.2373 $(M + H)^+$ (323.2375 calculated for $C_{23}H_{31}O$).

11-(3,4,5-Trimethoxyphenyl)-1-(2-hydroxy-4-methoxyphenyl)-undecan-1-one (**18e**) White waxy compound (410 mg, 81%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 12.89 (1H,s, OH), 7.65 (1H, d, $J = 8.8$ Hz, H-6″), 6.44–6.42 (2H, m, H-3″, 5″), 6.39 (2H, s, H-2′, 6′), 3.84 (6H, s, OCH_3), 3.82 (6H, s, OCH_3), 2.88 (2H, t, $J = 7.6$ Hz, H-2), 2.54 (2H, t, $J = 8.0$ Hz, H-11), 1.76–1.68 (4H, m, H-3, 10), 1.32 (12H, m, H-4, 5, 6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 205.1 (C-1), 165.9 (C-4″), 165.4 (C-2″), 153.0 (C-3′, 5′), 138.6 (C-1′), 138.5 (C-6″), 136.1 (C-4′), 113.5 (C-1″), 107.4 (C-2′, 6′), 105.4 (C-5″), 100.9 (C-3″), 60.7 (OCH_3), 56.0 (OCH_3), 55.4 (OCH_3), 43.8 (C-2), 36.3 (C-11), 31.5 (C-10), 29.5 (C-6, 7, 8), 29.4 (C-5), 29.3 (C-9), 29.2 (C-4), 24.8 (C-3); LC-MS: *m/z* 457.4 $(M-H)^-$.

11-(3,4-Dimethoxyphenyl)-1-(2-hydroxy-4-methoxyphenyl)-undecan-1-one (**18f**) waxy solid (350 mg, 75%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 12.89 (1H, s, OH), 7.65 (1H, d, $J = 9.6$ Hz, H-6″), 6.78 (1H, d, $J = 8.8$ Hz, H-5′), 6.71–6.70 (2H, m, H-2′, 6′), 6.44–6.42 (2H, m, H-3″, 5″), 3.87 (3H, s, OCH_3), 3.85 (3H, s, OCH_3), 3.83 (3H, s, OCH_3), 2.88 (2H, t, $J = 7.2$ Hz, H-2), 2.54 (2H, t, $J = 7.6$ Hz, H-11), 1.76–1.68 (2H, m, H-10), 1.64–1.55 (2H, m, H-3), 1.35–1.26 (12H, m, H-4, 5, 6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 202.7 (C-1), 165.9 (C-4″), 148.8 (C-2″), 147.1 (C-3′), 135.6 (C-4′), 131.5 (C-1′), 120.2 (C-6″), 113.5 (C-6′), 111.9 (C-1″), 111.4 (C-2′, 5′), 107.5 (C-5″), 101.0 (C-3″), 55.9 (OCH_3), 55.8 (OCH_3), 55.5 (OCH_3), 43.8 (C-2), 37.9 (C-11), 35.5 (C-10), 31.6 (C-6, 7), 29.5 (C-8), 29.4 (C-5), 29.3 (C-9), 29.2 (C-4), 24.9 (C-3); LC-MS: *m/z* 429.4 $(M + H)^+$, 451.4 $(M + Na)^+$; Q-Tof: *m/z* 429.2703 $(M + H)^+$ (429.2700 calculated for $C_{26}H_{37}O_5$).

11-(4-Methoxyphenyl)-1-(2-hydroxy-4-methoxyphenyl)-undecan-1-one (**18g**) White solid (370 mg, 85%); mp 48–50 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 12.9 (1H, s, OH), 7.65 (1H, d, $J = 9.2$ Hz, H-6″), 7.08 (2H, d, $J = 8.4$ Hz, H-2′, 6′), 6.81 (2H, d, $J = 8.4$ Hz, H-3′, 5′), 6.44–6.42 (2H, m, H-3″, 5″), 3.83 (3H, s, OCH_3), 3.78 (3H, s, OCH_3), 2.88 (2H, t, $J = 7.6$ Hz, H-2), 2.53 (2H, t, $J = 7.6$ Hz, H-11), 1.73–1.67 (2H, m, H-10), 1.63–1.55 (2H, m, H-3), 1.30 (12H, brs, H-4, 5, 6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 202.8 (C-1), 165.9 (C-4″), 165.5 (C-2″), 157.7 (C-4′), 134.9 (C-6″), 131.6 (C-1′), 129.2 (C-2′, 6′), 113.7 (C-3′, 5′), 107.5 (C-5″), 101.0 (C-3″), 55.5 (OCH_3), 55.3 (OCH_3), 43.9 (C-2), 38.0 (C-11), 35.0 (C-10), 31.7 (C-6, 7), 29.5 (C-8), 29.4 (C-5), 29.3 (C-9), 29.2 (C-4), 24.9 (C-3); LC-MS: *m/z* 397 $(M-H)^-$; Q-Tof: *m/z* 399.2523 $(M + H)^+$ (399.2535 calculated for $C_{25}H_{35}O_4$).

11-(Phenyl)-1-(2-hydroxy-4-methoxyphenyl)-undecan-1-one (**18h**) White waxy compound (335 mg, 83%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 12.91 (1H, s, OH), 7.64 (1H, d, $J = 9.6$ Hz, H-6″), 7.26 (2H, t, $J = 7.2$ Hz, H-3′, 5′), 7.17 (2H, d, $J = 7.2$ Hz, H-2′, 6′), 7.15 (1H, t, $J = 7.2$ Hz, H-4′), 6.42 (1H, dd, $J = 7.2$, 2.4 Hz, H-5″), 6.41 (1H, d, $J = 2.4$ Hz, H-3″), 3.81 (3H, s, OCH_3), 2.87 (2H, t, $J = 7.6$ Hz, H-2), 2.59 (2H, t, $J = 7.6$ Hz, H-11), 1.74–1.67 (2H, m, H-10), 1.62–1.58 (2H, m, H-3), 1.30 (12H, s, H-4, 5, 6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 202.7 (C-1), 165.9 (C-4″), 165.9 (C-2″), 142.9 (C-1′), 142.8 (C-6″), 131.6 (C-2′, 6′), 128.4 (C-3′, 5′), 125.6 (C-5′), 113.6 (C-1″), 107.5 (C-5″), 101.0 (C-3″), 55.5 (OCH_3), 43.9 (C-2), 38.0 (C-11), 35.9 (C-10), 31.4 (C-6), 29.5 (C-7), 29.4 (C-8), 29.3 (C-5), 29.2 (C-9), 29.1 (C-4), 24.9 (C-3); LC-MS: *m/z* 367.3 $(M-H)^-$; Q-Tof: *m/z* 369.2421 $(M + H)^+$ (369.2430 calculated for $C_{24}H_{33}O_3$).

11-(3,4,5-Trimethoxyphenyl)-1-(3,4-dimethoxyphenyl)-undecan-1-one (**18i**) Oily compound (450 mg, 86%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.58 (1H, dd, $J = 1.6$,8.0 Hz, H-6″), 7.53 (1H, d, $J = 1.6$ Hz, H-2″), 6.85 (1H, d, $J = 8.4$, H-5″), 6.39 (2H, s, H-2′, 6′), 3.94 (3H, s, OCH_3), 3.93 (3H, s, OCH_3), 3.84 (3H, s, OCH_3), 3.82 (3H, s, OCH_3), 2.91 (2H, t, $J = 7.6$ Hz, H-2), 2.54 (2H, t, $J = 8.0$ Hz, H-11), 1.76–1.69 (2H, m, H-10), 1.60–1.56 (2H, m, H-3), 1.34–1.25 (12H, m, H-4, 5, 6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 199.2 (C-1), 153.2 (C-4″), 153.1 (C-3′, 5′), 149.1 (C-3″), 138.7 (C-1′), 136.2 (C-1″), 130.5 (C-4′), 122.6 (C-6″), 110.4 (C-2″), 110.1 (C-5″), 105.5 (C-2′, 6′), 60.8 (OCH_3), 56.1 (OCH_3), 56.0 (OCH_3), 55.9 (OCH_3), 38.1 (C-2), 36.4 (C-11), 31.5 (C-10), 29.5 (C-6, 7, 8), 29.4 (C-5), 29.3 (C-9), 29.2 (C-4), 24.7 (C-3); LC-MS: *m/z* 473.4 (M + H)+, 495.4 $(M + Na)^+$, 511.3 $(M + k)^+$; Q-Tof: *m/z* 473.2908 $(M + H)^+$ (473.2903 calculated for $C_{28}H_{41}O_6$).

11-(3,4-Dimethoxyphenyl)-1-(3,4-dimethoxyphenyl)-undecan-1-one (**18j**) White solid (410 mg, 84 %); mp 74–76 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.20 (1H, d, $J = 3.2$ Hz, H-6″), 6.99 (1H, dd, $J = 3.2$, 8.8 Hz, H-2″), 6.89 (1H, d, $J = 8.8$ Hz, H-5″), 6.78 (1H, d, $J = 8.4$ Hz, H-5′), 6.72–6.70 (2H, m, H-2′, 6′), 3.87 (3H, s, OCH_3), 3.85 (3H, s, OCH_3), 3.84 (3H, s, OCH_3), 3.78 (3H, s, OCH_3), 2.95 (2H,

t, $J = 7.6$ Hz, H-2), 2.54 (2H, t, $J = 7.6$ Hz, H-11), 1.69–1.62 (2H, m, H-10), 1.59–1.52 (2H, m, H-3), 1.30–1.25 (12H, m, H-4, 5, 6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 202.8 (C-1), 153.6 (C-4″), 152.8 (C-3″), 148.8 (C-3′), 147.1 (C-4′), 135.7 (C-1′), 129.2 (C-1″), 120.2 (C-6″), 119.4 (C-6′), 113.2 (C-2″), 111.9 (C-5″), 111.4 (C-2′, 5′), 56.1 (OCH_3), 55.9 (OCH_3), 55.84 (OCH_3), 55.8 (OCH_3), 43.7 (C-2), 35.6 (C-11), 31.6 (C-10), 29.5 (C-6, 7, 8), 29.4 (C-5), 29.3 (C-9), 29.2 (C-4), 24.4 (C-3); LC-MS: *m/z* 443.4 $(M + H)^+$, 465.3 $(M + Na)^+$, 481.3 $(M + K)^+$; Q-Tof: *m/z* 443.2805 $(M + H)^+$ (443.2797 calculated for $C_{27}H_{39}O_5$).

11-(4-Methoxyphenyl)-1-(3,4-dimethoxyphenyl)-undecan-1-one (**18k**) Oily compound (360 mg, 80%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.58 (1H, dd, $J = 1.6$, 8.4 Hz, H-6″), 7.53 (1H, d, $J = 1.6$ Hz, H-2″), 7.08 (2H, d, $J = 8.4$ Hz, H-2′, 6′), 6.87 (1H, d, $J = 8.4$ Hz, H-5″), 6.81 (2H, d, $J = 8.8$ Hz, H-3′, 5′), 3.94 (3H, s, OCH_3), 3.93 (3H, s, OCH_3), 3.78 (3H, s, OCH_3), 2.91 (2H, t, $J = 7.2$ Hz, H-2), 2.53 (2H, t, $J = 7.6$ Hz, H-11), 1.74–1.68 (2H, m, H-10), 1.58–1.55 (2H, m, H-3), 1.38–1.28 (12H, m, H-4, 5, 6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 199.2 (C-1), 157.7 (C-4′), 153.2 (C-4″), 149.1 (C-3″), 135.1 (C-1′), 130.5 (C-1″), 129.2 (C-2′, 6′), 122.7 (C-6″), 113.7 (C-2″), 110.4 (C-5″), 110.1 (C-3′, 5′), 56.1 (OCH_3), 56.0 (OCH_3), 55.3 (OCH_3), 38.2 (C-2), 35.1 (C-11), 31.7 (C-10), 29.6 (C-6, 7, 8), 29.5 (C-5), 29.4 (C-9), 29.3 (C-4), 24.8 (C-3); LC-MS: *m/z* 413.3 $(M + H)^+$, 435.2 $(M + Na)^+$, 451.2 $(M + K)^+$; Q-Tof: *m/z* 413.2704 $(M + H)^+$ (413.2692 calculated for $C_{26}H_{37}O_4$).

11-(Phenyl)-1-(3,4-dimethoxyphenyl)-undecan-1-one (**18l**) white waxy compound (325 mg, 77%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.58 (1H, dd, $J = 1.6$, 8.4 Hz, H-6″), 7.53 (1H, d, $J = 1.6$ Hz, H-2″), 7.26 (2H, t, $J = 8.0$ Hz, H-3′, 5′), 7.17 (2H, d, $J = 7.2$ Hz, H-2′, 6′), 7.16 (1H, t, $J = 7.2$ Hz, H-4′), 6.87 (1H, d, $J = 8.4$ Hz, H-5″), 3.94 (3H, s, OCH_3), 3.93 (3H, s, OCH_3), 2.91 (2H, t, $J = 7.2$ Hz, H-2), 2.59 (2H, t, $J = 7.6$ Hz, H-11), 1.75–1.68 (2H, m, H-10), 1.62–1.57 (2H, m, H-3), 1.39–1.26 (12H, m, H-4, 5, 6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 199.2 (C-1), 153.2 (C-4″), 149.1 (C-3″), 142.9 (C-1′), 130.5 (C-1″), 128.4 (C-3′, 5′), 128.2 (C-2′, 6′), 125.5 (C-4′), 122.6 (C-6″), 110.3 (C-2″), 110.0 (C-5″), 56.0 (OCH_3), 55.9 (OCH_3), 38.2 (C-2), 35.9 (C-11), 31.5 (C-10), 29.5 (C-6, 7, 8), 29.47 (C-5), 29.40 (C-9), 29.3 (C-4), 24.8 (C-3); LC-MS: *m/z* 383.3 $(M + H)^+$, 405.3 $(M + Na)^+$, 421.3 $(M + K)^+$; Q-Tof: *m/z* 383.2601 $(M + H)^+$ (383.2586 calculated for $C_{25}H_{35}O_3$).

11-(3,4,5-Trimethoxyphenyl)-1-(2,5-dimethoxyphenyl)-undecan-1-one (**18m**) Oily compound, (420 mg, 81%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.20 (1H, d, $J = 3.2$ Hz, H-6″), 6.99 (1H, dd, $J = 3.2$, 8.8 Hz, H-4″), 6.89 (1H, d, $J = 8.0$ Hz, H-3″), 6.39 (2H, s, H-2′, 6′), 3.86 (9H, s, OCH_3), 3.82 (3H, s, OCH_3), 3.78 (3H, s, OCH_3), 2.95 (2H, t, $J = 7.2$ Hz, H-2), 2.54 (2H, t, $J = 8.0$ Hz, H-11), 1.66–1.60 (6H, m, H-3, 4, 10), 1.31–1.29 (10H, m, H-5, 6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 202.8 (C-1), 153.6 (C-2″), 153.1 (C-5″), 152.8 (C-3′, 5′), 138.7 (C-1′), 136.2 (C-4′), 129.2 (C-1″), 119.4 (C-4″), 114.1 (C-6″), 113.2 (C-3″), 105.5 (C-2′, 6′), 60.6 (OCH_3), 56.1 (OCH_3), 55.8 (OCH_3), 43.7 (C-2), 36.4 (C-11), 31.5 (C-10), 29.5 (C-6, 7, 8), 29.4 (C-5), 29.3 (C-9), 29.2 (C-4), 24.4 (C-3); LC-MS: *m/z* 473.4 (M + H)+, 495.4 $(M + Na)^+$; Q-Tof: *m/z* 473.2917 $(M + H)^+$ (473.2903 calculated for $C_{28}H_{41}O_6$).

11-(3,4-Dimethoxyphenyl)-1-(2,5-dimethoxyphenyl)-undecan-1-one (**18n**) Waxy compound (405 mg, 83%); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.58 (1H, dd, $J = 1.6$, 8.4 Hz, H-6″), 7.53 (1H, d, $J = 1.6$ Hz, H-4″), 6.88 (1H, d, $J = 8.4$ Hz, H-3″), 6.78 (1H, d, $J = 7.6$ Hz, H-5′), 6.71–6.70 (2H, m, H-2′, 6′), 3.94 (3H, s, OCH_3), 3.93 (3H, s, OCH_3), 3.87 (3H, s, OCH_3), 3.85 (3H, s, OCH_3), 2.91 (2H, t, $J = 7.6$ Hz, H-2), 2.54 (2H, t, $J = 7.6$ Hz, H-11), 1.75–1.68 (2H, m, H-10), 1.59–1.54 (2H, m, H-3), 1.299 (12H, brs, H-4, 5, 6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 199.2 (C-1), 153.2 (C-2″), 149.1 (C-5″), 148.8 (C-3′), 147.1 (C-4′), 135.7 (C-1′), 130.5 (C-1″), 122.6 (C-6′), 120.2 (C-4″), 111.9 (C-6″), 111.4 (C-3″), 110.4 (C-2′), 110.1 (C-6′), 56.0 (OCH_3), 55.9 (OCH_3), 55.8 (OCH_3), 38.1 (C-2), 35.6 (C-11), 29.5 (C-10), 29.4 (C-5, 6, 7, 8), 29.3 (C-9), 29.2 (C-4), 24.8 (C-3); LC-MS: *m/z* 443.4 $(M + H)^+$, 465.4 $(M + Na)^+$; Q-Tof: *m/z* 443.2792 $(M + H)^+$ (443.2797 calculated for $C_{27}H_{39}O_5$).

11-(4-Methoxyphenyl)-1-(2,5-dimethoxyphenyl)-undecan-1-one (**18o**) White solid (390 mg, 86%); mp 78–82 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.21 (1H, d, $J = 3.2$ Hz, H-6″), 7.08 (2H, d, $J = 8.8$ Hz, H-2′, 6′), 6.99 (1H, dd, $J = 3.2$, 8.8 Hz, H-4″), 6.88 (1H, d, $J = 8.8$ Hz, H-3″), 6.81 (2H, d, $J = 8.8$ Hz, H-3′, 5′), 3.84 (3H, s, OCH_3), 3.78 (3H, s, OCH_3), 3.77 (3H, s, OCH_3), 2.95 (2H, t, $J = 7.2$ Hz, H-2), 2.53 (2H, t, $J = 8.0$ Hz, H-11), 1.67–1.54 (4H, m, H-3,10), 1.29–1.27 (12H, m, H-4, 5, 6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 202.8 (C-1), 157.7 (C-4′), 153.6 (C-2″), 152.9 (C-5″), 135.1 (C-1′), 129.2 (C-2′, 6′), 122.1 (C-1″), 119.5 (C-4″), 114.1 (C-6″), 113.7 (C-3″), 113.2 (C-3′, 5′), 56.2 (OCH_3), 55.8 (OCH_3), 55.3 (OCH_3), 43.8 (C-2), 35.1 (C-11), 31.7 (C-10), 29.6 (C-6, 7, 8), 29.5 (C-5), 29.4 (C-9), 29.3 (C-4), 24.5 (C-3); LC-MS: *m/z* 413.3 $(M + H)^+$, 435.3 $(M + Na)^+$, 451.2 $(M + K)^+$; Q-Tof: *m/z* 413.2690 $(M + H)^+$ (413.2692 calculated for $C_{26}H_{37}O_4$).

11-(Phenyl)-1-(2,5-dimethoxyphenyl)-undecan-1-one (**18p**) White solid, (340 mg, 81%); mp 68–70 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.26 (2H, t, $J = 8.0$ Hz, H-6″), 7.21 (1H, d, $J = 3.2$ Hz, H-4″), 7.16 (2H, d, $J = 7.2$ Hz, H-

3′, 5′), 7.15 (1H, t, $J = 7.2$ Hz, H-2′, 6′), 6.99 (1H, dd, $J = 2.8$, 8.8 Hz, H-4′), 6.88 (1H, d, $J = 9.2$ Hz, H-3″), 3.84 (3H, s, OCH_3), 3.78 (3H, s, OCH_3), 2.95 (2H, t, $J = 7.6$ Hz, H-2), 2.59 (2H, t, $J = 7.2$ Hz, H-11), 1.67–1.58 (4H, m, H-3, 10), 1.29–1.27 (12H, m, H-4, 5, 6, 7, 8, 9); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 202.8 (C-1), 153.6 (C-2″), 152.8 (C-5″), 142.9 (C-1′), 129.2 (C-2′, 6′), 128.4 (C-3′, 5′), 128.2 (C-4′), 125.5 (C-1″), 119.4 (C-4″), 114.1 (C-6″), 113.2 (C-3″), 56.1 (OCH_3), 55.8 (OCH_3), 43.7 (C-2), 35.9 (C-11), 31.5 (C-10), 29.5 (C-6, 7, 8), 29.48 (C-5), 29.40 (C-9), 29.3 (C-4), 24.4 (C-3); LC-MS: *m/z* 383.3 $(M + H)^+$, 405.3 $(M + Na)^+$; Q-Tof: *m/z* 383.2588 $(M + H)^+$ (383.2586 calculated for $C_{25}H_{35}O_3$).

5-Lipoxygenase inhibitory activity

5-Lipoxygenase enzyme inhibitory activity was measured by Schewe et al. (Schewe et al. 1986) method, which was modified by Reddanna et al. (Reddenna et al. 1990). The assay mixture contained 80 µM linoleic acid and potato 5-lipoxygenase in 50 mM phosphate buffer (pH 6.3). The reaction was initiated by the addition of enzyme buffer mix to linoleic acid and the enzyme activity was monitored as the increase in absorbance at 234 nm. The reaction was monitored for 120 sec and the inhibitory potential of the test substances **15, 18a–p** were measured by incubating various concentrations of test substances for 2 min before the addition of linoleic acid. All assays were performed in triplicate. Percentage inhibition was calculated and the results are summarized in Table 1.

Brine shrimp lethality bioassay

Brine shrimp (*Artemiasalina*) nauplii were hatched using brine shrimp eggs (Meyer et al. 1982) in a conical shaped vessel (1 L), filled with sterile artificial sea water (prepared using sea salt 38 g/L and adjusted to pH 8.5 using 1N NaOH) under constant aeration for 48 h. After hatching, 10 nauplii were drawn through a pipette and placed in each vial containing 4.5 mL brine solution and treated with various concentrations of test substances and the final volume was made up to 5 mL using brine solution and the cultures maintained at 37 °C for 24 h under incandescent lamps. The surviving larvae were counted. Each experiment was conducted along with control (vehicle treated), at various concentrations of the test substance with each set containing 6 tubes and averages of the results were noted in the table. The percentage lethality was determined by comparing the mean surviving larvae of test and control tubes. The IC_{50} values were obtained from the plot drawn containing concentration (µM) verses percentage lethality. Podophyllotoxin was used as a positive control. The results are summarized in Table 1.

Table 1 Biological activities of ardisinone E (**15**) and diarylundecanones

S.No	Compound	5-LOX IC_{50} µg/mL	Anti-oxidant NBT(IC_{50} µg/mL)	Brine shrimp ED_{50} µg/mL
1	**15**	>100	56.64	4.19
2	**18c**	62.10	18.75	50.51
3	**18e**	12.80	12.28	63.14
4	**18f**	32.03	50.04	85.64
5	**18J**	35.54	18.35	70.38
6	**18k**	15.23	11.04	44.67
7	**18l**	24.60	12.05	44.32
8	**18m**	15.23	11.32	60.09
9	**18o**	43.35	>100	70.15
10	**18p**	53.51	28.12	65.53
11	Gallic acid	–	2.34	–
12	Podophyllotoxin	–	–	1.92
13	Curcumin	8.98	–	–

Superoxide radical scavenging activity

Superoxide radical scavenging activity of compounds **15, 18a–p** was determined spectrophotometrically (560 nm) by adopting the nitro blue tetrazolium (NBT) photo reduction method of McCord and Fridovich (Mc Cord and Fridovich 1969). The assay mixture contained EDTA (6.6 µM), NaCN (3 µg), riboflavin (2 µM), NBT (50 µM), test substance and phosphate buffer (58 mmol, pH 7.8) in a final volume of 3 mL. Each mixture in a tube was shaken well, and the optical density was measured at 560 nm. Each tube was then uniformly illuminated with an incandescent lamp for 15 min, and the optical density was measured again at 560 nm. The percentage inhibition of superoxide radical-generation was measured by comparing the absorbance values of the control and that of the test substance. The IC_{50} values were obtained from a plot drawn between concentrations (µM) vs. the percentage inhibition. The super-oxide radical's inhibitions exhibited by compounds **15, 18a–p** have been summarized in Table 1.

Conclusion

Ardisinone E (**15**) a naturally occurring diarylundecanone derivative and 16 new undecanone analogs were prepared successfully and were characterized by their spectral data. Ardisinone E (**15**) showed potent cytotoxic activity in brine shrimp lethality assay, which could be attributable to the

number of hydroxyl groups present in the molecule. The compounds **18b**, **18n**, **18p** with more number of methoxyl goups showed good anti-inflammatory activity. The compounds containing hydroxyl group adjacent to the keto functional group and also compounds with few number of methoxy groups exhibited reasonable anti-oxidant activity.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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