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Ultrasound-assisted convenient synthesis of hypolipidemic active natural methoxylated (*E*)-arylalkenes and arylalkanones☆

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Abstract—An ultrasound-assisted convenient method was developed for the conversion of toxic methoxylated *cis*-isomer of arylalkenes into its hypolipidemic active *trans*-isomer. Treatment of *cis*-isomer or mixture of all three isomers (**1a**–**1j**) with ammonium formate and 10% Pd/C gave arylalkanes (**2a**–**2j**), which upon oxidation with DDQ in anhydrous dioxane containing a little amount of silica gel, provided (*E*)-arylalkenes (**3a**–**3g**) in 42–72% yield depending upon the substituents attached at the aryl ring. The same method, upon addition of a few drops of water, provided hypolipidemic active arylalkanones (**3h**–**3j**) in 59–65% yield.

1. Introduction

Hypercholesterolemia[1] appears to be a serious risk factor for coronary heart diseases (CHDs). High level of low-density lipoprotein (LDL) are recognized as the initiating event in CHDs. LDL can undergo extensive lipid peroxidation, resulting in the generation of modified LDL and the formation of atheromatic lesions. Hence, implementation of hypolipidemic drugs in any heart disease prevention therapy is an imperative strategy. In this regards, various hypolipidemic drugs[2] such as statins, clofibrate, niacins etc. are found effective. On the other side, a large number of plant extracts[3] as well as natural molecules[4] including phenylpropanoids[5] and phenylbutanoids[5b,6] have also shown promising results. Among them, some methoxylated phenylpropanoids and phenylbutanoids like (*E*)-arylalkenes[7] (such as α-asarone) (**3a**–**3g**) and arylalkanones[7,8] (such as isoacoramone) (**3h**–**3j**) are reported to be active hypolipidemic agents. Besides possessing hypolipidemic activities, these natural compounds (**3a**–**3j**) are known to have a wide range of biological[9] activities such as neuroleptic, anti-ulcerogenic, anti-atherogenic, anti-inflammatory, anti-choleretic, anti-PAF, anti-fungal and anti-platelet activities. Various synthetic methods are reported for (*E*)-arylalkenes which involve Grignard,[10] Wittig–Horner,[11] Aldol–Grob,[12] Wittig,[6] Friedel–Crafts[7] and photochemical isomerization[13] reactions. However, all the above methods result in formation of some amount of unwanted toxic[14] *cis*-isomer[15] along with the desired *trans*-isomer and it becomes difficult to separate them through column purification[16] due to resemblance in R_f values of both the isomers. Recent development of disodium iron tetracarbonyl, iridium and palladium(II) catalyzed isomerization of *gamma*[17] and *cis*-arylalkenes[18] is a very useful entry to (*E*)-arylalkene synthesis. However, expensive reagents limit its scope for a large scale synthesis. As for the synthesis of aforementioned hypolipidemic arylalkanones **3h**–**3j**, a lot of methods[19] are reported which mainly involve Grignard[10] and Friedel–Crafts[7] approaches. Overall, all the synthetic methods mentioned above suffer from some drawbacks such as long reaction time, tedious workups, expensive and hazardous reagents and starting materials. Keeping this in mind, it would, therefore, be useful to utilize inexpensive and abundantly available isomeric mixture of arylalkenes in a reliable, mild, economical and environment friendly manner for the synthesis of title compounds. In this context, we, herein, report an ultrasound-assisted[20] convenient method for the preparation of methoxylated (*E*)-arylalkenes (**3a**–**3g**) and arylalkanones (**3h**–**3j**) via DDQ-assisted oxidation of arylalkanes (**2a**–**2j**) obtained by hydrogenation of isomeric mixture of arylalkenes (**1a**–**1j**) (Scheme 1).

2. Results and discussion

As per our continuing efforts towards chemical modification of abundantly[15] available toxic[14] (*Z*)-1-(2′,4′,5′-trimethoxyphenyl)prop-1-ene (commonly known as β-asarone) (**1a**) into value added products,[21] synthesis of hypolipidemic (*E*)-1-(2′,4′,5′-trimethoxyphenyl)prop-1-ene

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Keywords: Hypolipidemic; Ultrasound; (*E*)-Arylalkenes; Arylalkanones; DDQ.
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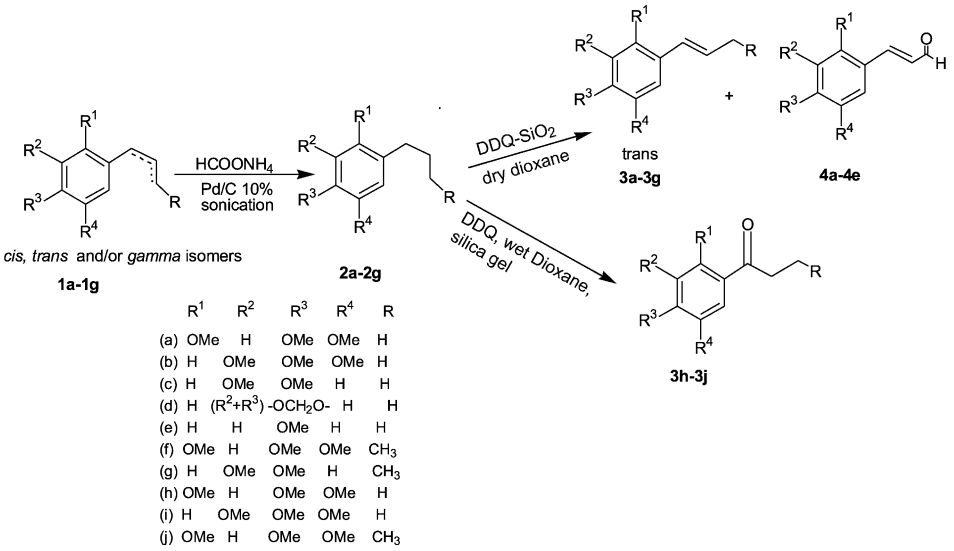


Scheme 1.

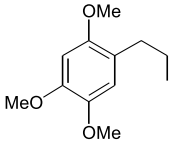
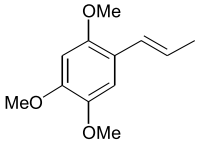
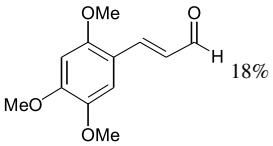
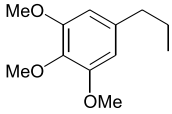
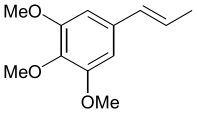
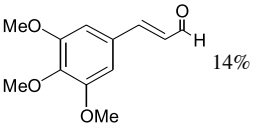
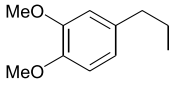
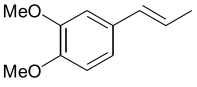
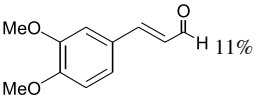
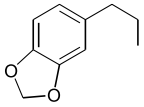
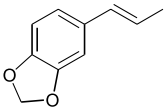
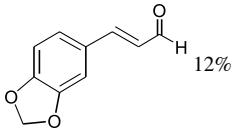
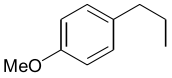
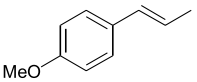
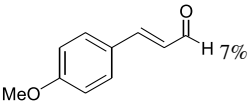
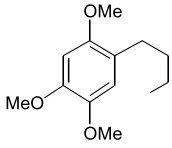
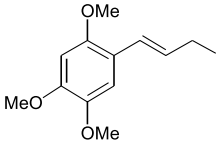
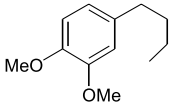
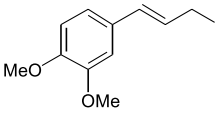
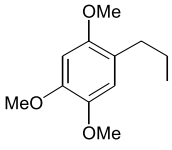
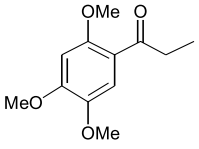
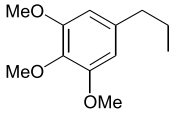
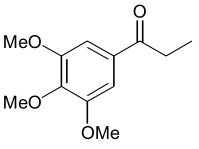
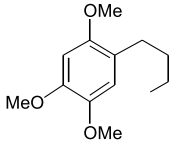
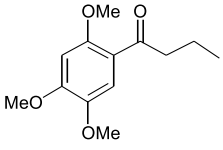
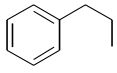
α-asarone) (**3a**) was undertaken from **1a** as a starting compound. Treatment of **1a**, containing an isomeric mixture of α- and/or γ-asarone (3-(2′,4′,5′-trimethoxyphenyl)prop-1-ene), with ammonium formate[22] and Pd/C provided 1-(2′,4′,5′-trimethoxyphenyl)propane[23] (dihydroasarone) (**2a**) in quantitative yield in 30 min while conventional method required 10–12 h for complete hydrogenation of **1a** into **2a**. In the next step, dehydrogenation of **2a** into **3a** was attempted with various dehydrogenating reagents[24] such as Pd–C in diphenylether, SeO_2 and chloranil but none were successful. In all the above conditions, the reaction did not go to completion, and mostly the starting **2a** remained unreacted. Later on, the attention was shifted to the use of 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ)[25] and reaction of **2a** with 1.0–1.1 M equiv of DDQ in dry toluene under nitrogen atmosphere, furnished the corresponding dehydrogenated product **3a** in 32% yield with a large amount of unreacted starting compound **2a**. Use of 1.25 M equiv of DDQ in toluene provided **3a** in 45% yield and it did not improve further, even when using excess of DDQ and refluxing the mixture for 20 h. Similarly, the above reaction was carried out in MeOH which afforded 23% of the product **3a** and rest of the starting **2a** remained unreacted. However, in 1,4-dioxane as solvent, reaction of **2a** with 1.25 equiv DDQ increased the yield of **3a** up to 52% along with a yellow coloured side product, that is, (*E*)-3-(2′,4′,5′-trimethoxyphenyl)prop-2-en-1-al[26] (**4a**, 12% yield). There was no further improvement in the yield of **3a** with increasing the amount of DDQ. The spectroscopic analysis and comparison with the reported[7,26] data clearly indicated both **3a** and **4a** exclusively with *trans* selectivity. Interestingly, when a catalytic amount of pre-activated silica gel was added to the above reaction mixture, the yield of **3a** increased up to 72% with 18% yield of **4a** at room temperature under nitrogen atmosphere. This incremental effect due to silica gel was presumed to be due to its mild acidic nature which, in catalytic amounts, would initiate the protonation of DDQ and facilitate the reaction (Table 1). In order to increase the yield of **3a** further, we performed the same dehydrogenation reaction of **2a** under sonication[20] for 40 min. However, instead of increasing yield of **3a**, it increased the yield of **4a** up to 29% at the cost of desired **3a** which got reduced to 48%. Increase in the yield of **4a** could be due to the presence of atmospheric oxygen/moisture in the reaction mixture during sonication, which would form highly reactive peroxy radicals[27] to further oxidize **3a** into **4a**. It is evident from the fact that maintenance of nitrogen atmosphere during conventional method limits the yield of **4a** to 18% only.

Having been successful with the synthesis of **3a**, the combination of DDQ–silica-dioxane successfully converted **2b–2g**, dihydro products[23] of **1b–1g**, into **3b–3g** with a little amount of corresponding (*E*)-arylalkenals[26] (**4b–4e**) and no arylalkenals were detected in case of **2f–2g** (Table 2). After successful synthesis of a series of hypolipidemic (*E*)-arylalkenes (**3a–3g**), we shifted our focus towards synthesis of hypolipidemic arylalkanones **3h–3j**. In the same method of treatment of **2a** with DDQ–silica-dioxane, a few drops of water were added which provided **3h** in 43% yield with mere 7% of **3a**, without formation of any **4a**, within 10 h. Reaction conditions were optimized and 2.2 equiv of

Table 1. Oxidation of arylalkane (**2a**) into (*E*)-arylalkene (**3a**) with varying amounts of DDQ in different solvents

Entry	DDQ (in M equiv)	Solvents	Yield of **3a** (%)
1	1.0–1.1	Toluene	32
2	1.25	Toluene	45
3	1.50	Toluene	43
4	1.25	MeOH	23
5	1.25	1,4-Dioxane	52
6	1.25 + silica gel (cat.)	1,4-Dioxane	72
7	1.25 + silica gel (cat.) (under sonication)	1,4-Dioxane	48

Table 2. DDQ assisted oxidation of arylalkanes (**2**) into (*E*)-arylalkenes/arylalkanones (**3**) and (*E*)-arylalkenal (**4**)

Entry	Arylalkane (**2**)	Method[a]	*E*-Arylalkene/arylalkanone (**3**)	*E*-Arylalkenal (**4**)
a		A	 72%	 18%
b		A	 70%	 14%
c		A	 63%	 11%
d		A	 56%	 12%
e		A	 42%	 7%
f		A	 54%	—
g		A	 49%	—
h		B	 64%	—
i		B	 65%	—
j		B	 59%	—
k		A or B	—	—

[a] Method A: DDQ (1.25 equiv)/dry dioxane/silica gel; Method B: DDQ (2.2 equiv)/wet dioxane/silica gel.

DDQ[25] was found most suitable with **2a** and silica-dioxane-water to provide maximum yield of **3h** up to 57% within 10 h, whereas the same reaction provided 64% of **3h** in 20 min under sonication. No more increase in the yield of **3h** was observed by increasing either the sonication period or the heating temperature of the reaction mixture. Similarly, **3i**–**3j** got formed in 65 and 59%, yield respectively under sonication during oxidation of **2i**–**2j**. It was interesting that, oxidation of **2k** did not provide corresponding (*E*)-alkene or alkanone (**3k**) with either DDQ–silica-dioxane or DDQ–silica-dioxane-water-sonication, and mostly the starting material was recovered. This indicates that the presence of

methoxy group in the aryl ring plays an important role in the oxidation of **2a–2j** (Table 2). However, further studies regarding this mechanistic aspect influenced by the structural variation of the starting compounds is under progress. It is worth mentioning that the use of DDQ has so far been reported in the formation of arylpropenals[26] from arylpropenes, but removal of double bond of arylpropenes by conversion into arylpropanes followed by oxidation with DDQ is a new method for the formation of various bioactive compounds, including hypolipidemic (*E*)-arylalkenes (**3a–3g**) and arylalkanones (**3h–3j**).

3. Conclusion

In conclusion, we have realized an ultrasound-assisted convenient semi-synthetic approach towards preparation of a number of natural hypolipidemic compounds (**3a–3j**) from commercially available isomeric mixture of substituted arylalkenes (**1a–1j**) via intermediate arylalkanes (**2a–2j**). Moreover, our studies strongly emphasize the change in the products from arylalkenes (**3a–3g**) on one side to arylalkanones (**3h–3j**) on the other, with a little change in the ratio of DDQ and the reaction conditions from anhydrous to aqueous medium.

4. Experimental

4.1. General methods

Melting points were determined with a Mettler FP80 micromelting point apparatus and are uncorrected. Column chromatography was performed on silica gel (60–120 mesh size). ^{1}H (300 MHz) NMR spectra was recorded in $CDCl_3$ on a Bruker Avance-300 spectrometer. Sonication (20 kHz, 400 W; Pulse length:10 s; 75% duty) was used for all the given reactions.

4.2. General procedure for ultrasound-assisted conversion of toxic methoxylated *cis*-arylalkenes containing an isomeric mixture of *trans* and *gamma*-isomers (1a–1k) into arylalkanes (2a–2k)

The isomeric mixture of methoxylated arylalkenes **1a–1k** (0.044 mol), 10% Pd/C (0.75–1.20 g) and ammonium formate (0.41 mol) in ethanol (200 mL) was sonicated for 30–40 min. After completion of the reaction, the catalyst was removed by filtration and the filtrate was evaporated. The residue was partitioned between ethyl acetate (70 mL) and water (15 mL) and the ethyl acetate layer was washed with water (2×10 mL), 10% HCl (2×5 mL), brine (2×10 mL), dried over Na_2SO_4 and filtered. The filtrate was evaporated and the obtained residue was purified by column chromatography (silica gel, hexane:ethyl acetate::9:1) to afford arylalkane **2a–2k** in quantitative yield whose spectra were found matching with the reported values.[23]

4.3. General procedure for dehydrogenation of methoxylated arylalkanes (2a–2g) into (*E*)-arylalkenes (3a–3g)

Arylalkane **2a–2g** (2.4 mmol), DDQ (3.0 mmol), silica gel (0.2–0.3 g, kept at 110–120 °C for 3–4 h before use) in anhydrous dioxane (30 mL) was stirred at room temperature for 12–14 h under nitrogen atmosphere till completion of the reaction. The precipitated $DDQH_2$ was filtered and the filtrate was evaporated and subsequently chromatographed on silica gel (hexane:ethyl acetate::7:3) to provide **3a–3g** in 42–72% yield along with some amount of (*E*)-arylalkenal (**4a–4e**) (Table 2). The spectral data of compounds (**3a–3g** and **4a–4e**) agreed well with the reported values.[7,8,10,17c,18,21,23,28]

4.3.1. 1-(2′,4′,5′-Trimethoxyphenyl)prop-1-ene (3a).[7b] Yield 72%; white solid; mp 44–45 °C (lit.[7b] mp 44–45 °C); ^{1}H NMR ($CDCl_3$): δ 6.91 (1H, s, H-6′), 6.64 (1H, dq, J=16.0, 1.5 Hz, H-1), 6.45 (1H, s, H-3′), 6.02 (1H, dq, J=16.0, 6.2 Hz, H-2), 3.84, 3.81 and 3.77 (each 3H, s, three OCH_3),1.87 (3H, dd, J=6.2, 1.5 Hz, H-3).

4.3.2. 1-(3′,4′,5′-Trimethoxyphenyl)prop-1-ene (3b).[7b] Yield 70%; liquid; ^{1}H NMR ($CDCl_3$): δ 6.50 (2H, s, H-2′ and H-6′), 6.31 (1H, dq, J=15.7, 1.4 Hz, H-1), 6.12 (1H, dq, J=15.7, 6.3 Hz, H-2), 3.81 (3H, s, OCH_3), 3.78 (6H, s, two OCH_3), 1.82 (3H, dd, J=6.3, 1.4 Hz, H-3).

4.3.3. 1-(3′,4′-Dimethoxyphenyl)prop-1-ene (3c).[17c] Yield 63%; liquid; ^{1}H NMR ($CDCl_3$): δ 6.90–6.78 (3H, m, H-2′, H-5′ and H-6′), 6.35 (1H, d, J=16.2 Hz, H-1), 6.22–6.11 (1H, m, H-2), 3.87 and 3.83 (each 3H, s, two OCH_3), 1.87 (3H, d, J=6.2 Hz, H-3).

4.3.4. 1-(3′,4′-Dioxymethylenephenyl)prop-1-ene (3d).[8] Yield 56%; Liquid; ^{1}H NMR ($CDCl_3$): δ 6.92–6.77 (3H, m, H-2′, H-5′ and H-6′), 6.35 (1H, d, J=16.2 Hz, H-1), 6.25–6.11 (1H, m, H-2), 5.95 (2H, s, –OCH_2O–), 1.95 (3H, d, J=6.2 Hz, H-3).

4.3.5. 1-(4′-Methoxyphenyl)prop-1-ene (3e).[17c] Yield 42%; liquid; ^{1}H NMR ($CDCl_3$): δ 7.07–6.96 (2H, m, H-2′ and H-6′), 6.88–6.80 (2H, m, H-3′ and H-5′), 6.39 (1H, d, J=16.2 Hz, H-1), 6.18–6.11 (1H, m, H-2), 3.83 (3H, s, OCH_3), 1.87 (3H, d, J=6.2 Hz, H-3).

4.3.6. 1-(2′,4′,5′-Trimethoxyphenyl)-1-butene (3f).[6a] Yield 54%; mp 40–41 °C (reported as a pale yellow liquid in literature[6a]); ^{1}H NMR ($CDCl_3$): δ 6.82 (1H, s, H-6′), 6.54 (1H, d, J=16.2 Hz, H-1), 6.29 (1H, s, H-3′), 5.96 (1H, m, H-2), 3.66 (6H, s, two OCH_3), 3.60 (3H, s, OCH_3), 2.08 (2H, m, H-3), 0.93 (3H, t, J=7.1 Hz, H-4).

4.3.7. 1-(3′,4′-Dimethoxyphenyl)-1-butene (3g).[6a] Yield 49%; liquid; ^{1}H NMR ($CDCl_3$): 6.90–6.79 (3H, m, H-2′, H-5′ and H-6′), 6.51 (1H, d, J=16.1 Hz, H-1), 5.42 (1H, m, H-2), 3.84 and 3.81 (each 3H, s, two OCH_3), 2.21 (2H, m, H-3), 1.02 (3H, t, J=7.0 Hz, H-4).

4.3.8. 3-(2′,4′,5′-Trimethoxyphenyl)prop-2-en-1-al (4a).[26] Yield 18%; yellow solid; mp 139–140 °C (lit.[26] 140–142 °C); ^{1}H NMR (300 MHz, $CDCl_3$): δ 9.65 (1H, d, J=7.8 Hz, H-1), 7.81 (1H, d, J=15.8 Hz, H-3), 7.03 (1H, s, H-6′), 6.64 (1H, dd, J=15.8, 7.8 Hz, H-2), 6.51 (1H, s, H-3′), 3.95, 3.91 and 3.87 (each 3H, s, three OCH_3).

4.3.9. 3-(3′,4′,5′-Trimethoxyphenyl)-prop-2-en-1-al (4b).[26] Yield 14%; yellow solid; mp 110 °C (lit.[26] 109–111 °C); ^{1}H NMR ($CDCl_3$): δ 9.68 (1H, d, J=7.8 Hz, H-1), 7.58 (1H, d, J=15.8 Hz, H-3), 6.63 (1H, dd, J=15.8, 7.8 Hz, H-2), 6.26 (2H, s, H-2′ and H-6′), 3.73 (9H, s, three OCH_3).

4.3.10. 3-(3′,4′-Dimethoxyphenyl)prop-2-en-1-al (4c). Yield 11%; mp 78 °C (lit.[28] mp 78–79 °C); ^{1}H NMR ($CDCl_3$): δ 9.67 (1H, d, J=7.8 Hz, H-1), 7.43 (1H, d, J=15.8 Hz, H-3), 7.15 (1H, d, J=8.1 Hz, H-6′), 7.08 (1H, s, H-2′), 6.91 (1H, d, J=8.1 Hz, H-5′), 6.61 (1H, dd, J=15.8, 7.8 Hz, H-2), 3.94 and 3.93 (each 3H, s, two OCH_3).

4.3.11. 3-(3′,4′-Dioxymethylenephenyl)prop-2-en-1-al (4d). Yield 12%; mp 78 °C (lit.[28] mp 77 °C); ^{1}H NMR ($CDCl_3$): δ 9.88 (1H, d, J=7.8 Hz, H-1), 7.38 (1H, d, J=15.8 Hz, H-3), 6.75 (1H, d, J=8.2 Hz, H-6′), 6.70 (1H, s, H-2′), 6.63 (1H, d, J=8.2 Hz, H-5′), 6.56 (1H, dd, J=15.8, 7.8 Hz, H-2), 6.10 (2H, s, –OCH_2O–).

4.3.12. 3-(4′-Methoxyphenyl)prop-2-en-1-al (4e).[28] Yield 7%; white solid, mp 58–59 °C (lit.[28] mp 59 °C); ^{1}H NMR ($CDCl_3$): δ 9.68 (1H, d, J=7.8 Hz, H-1), 7.58 (1H, d, J=15.8 Hz, H-3), 7.19 (2H, m, H-2′ and H-6′), 6.72 (2H, m, H-3′ and H-5′), 6.63 (1H, dd, J=15.8, 7.8 Hz, H-2), 3.73 (3H, s, OCH_3).

4.4. General procedure for ultrasound-assisted synthesis of methoxylated arylalkanones (3h–3j) from oxidation of arylalkanes (2a–2b and 2f) with DDQ

A mixture of substituted arylalkane (**2a**–**2b** and **2f**) (2.4 mmol), DDQ (4.8–5.24 mmol), 10% HCl (1–2 drops) in wet dioxane (30 mL, dioxane:water::90:10) was stirred under sonication for 20 min. The precipitated $DDQH_2$ was filtered and the red coloured filtrate was evaporated and subsequently chromatographed on silica gel (hexane:ethyl acetate 7:3) to provide **3h**–**3j** in 59–65% yield (Table 2). The spectral data of compounds (**3h**–**3j**) agreed well with the reported values.[7,8,21]

4.4.1. 1-(2′,4′,5′-Trimethoxyphenyl)-1-propanone (also known as isoacoramone) (3h).[7] Yield 64%; White solid; mp 108–109 °C (lit.[7] mp 109 °C); ^{1}H NMR ($CDCl_3$) δ 7.45 (1H, s, H-6′), 6.77 (1H, s, H-3′), 3.96, 3.93 and 3.89 (each 3H, s, three –OCH_3), 2.99 (2H, q, J=6.9 Hz, H-2), 1.18 (3H, t, J=6.9 Hz, H-3).

4.4.2. 1-(3′,4′,5′-Trimethoxyphenyl)-1-propanone (3i).[7] Yield 65%; White solid; mp 52–53 °C (lit.[7] mp 53 °C); ^{1}H NMR ($CDCl_3$) δ 7.23 (2H, s, H-2′ and H-6′), 3.90 (9H, s, three –OCH_3), 2.95 (2H, q, J=7.2 Hz, H-2), 1.22 (3H, t, J=7.2 Hz, H-3).

4.4.3. 1-(2′,4′,5′-Trimethoxyphenyl)-1-butanone (3j). Yield 59%; White solid; mp 75–76 °C (lit.[7] mp 75–77 °C); ^{1}H NMR ($CDCl_3$) δ 7.34 (1H, s, H-6′), 6.41 (1H, s, H-3′), 3.85, 3.82 and 3.78 (each 3H, s, three –OCH_3), 2.87 (2H, t, J=7.4 Hz, H-2), 1.67–1.55 (2H, m, H-3), 0.89 (3H, t, J=7.4 Hz, H-4).

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References and notes

1. (a) Neil, H. A.; Mant, D.; Jones, L.; Morgan, B.; Mann, J. I. *Br. Med. J.* **1990**, *301*, 584. (b) McCully, K. S. *Nat. Med.* **1996**, *2*, 386. (c) Chrysselis, M. C.; Rekka, E. A.; Kourounakis, P. N. *J. Med. Chem.* **2000**, *43*, 609.
2. (a) Mantell, G.; Burke, M. T.; Staggers, J. *Am. J. Cardiol.* **1990**, *66*, B11. (b) Ceska, R.; Melenovsky, V.; Malik, J.; Kralikova, E.; Stulc, T.; Vrablik, M. *Int. Congress Ser.* **2004**, *1262*, 458.
3. (a) Chen, C. C.; Hsu, J. D.; Wang, S. F.; Chiang, H. C.; Yang, M. Y.; Kao, E. S.; Ho, Y. C.; Wang, C. J. *J. Agric. Food Chem.* **2003**, *51*, 5472. (b) Allen, K. G. D.; Bristow, S. J.; Yu, L. *J. Agric. Food Chem.* **2004**, *52*, 4998.
4. (a) Ramírez-Tortosa, M. C.; Mesa, M. D.; Aguilera, M. C.; Quiles, J. L.; Baro, L.; Ramírez-Tortosa, C. L.; Martinez-Victoria, E.; Gil, A. *Atherosclerosis* **1999**, *147*, 371. (b) Huang, K. C. *The Pharmacology of Chinese Herbs*; CRC: New York, 1999; pp 117–127. (c) Winklhofer-Roob, B. M.; Rock, E.; Ribalta, J.; Shmerling, D. H.; Roob, J. M. *Mol. Aspects Med.* **2003**, *24*, 391. (d) Vastano, B. C.; Chen, Y.; Zhu, N.; Ho, C. T.; Zhou, Z.; Rosen, R. T. *J. Agric. Food Chem.* **2000**, *48*, 253.
5. (a) Enqiquez, R. G.; Chávez, M. A.; Jáuregui, F. *Phytochemistry* **1980**, *19*, 2024. (b) Harborne, J. B.; Baxter, H. *Phytochemical Dictionary: A Handbook of Bioactive Compounds from Plants*; Taylor & Francis: Washington, DC, 1993.
6. (a) Tuntiwachwuttikul, P.; Pancharoen, O.; Jaipetch, T.; Reutrakul, V. *Phytochemistry* **1981**, *20*, 1164. (b) Bhandari, U.; Sharma, J. N.; Zafar, R. *J. Ethnopharmacol.* **1998**, *61*, 167.
7. (a) Francisco, D.; Leticia, C.; Rosa, F.; Joaquin, T.; Fernando, L.; German, C.; Heber, M. *Org. Prep. Proced. Int.* **1991**, *23*, 133. (b) Janusz, P.; Bozena, L.; Alina, T. D.; Barbara, L.; Stanislaw, W.; Danuta, S.; Jacek, P.; Roman, K.; Jacek, C.; Malgorzata, S.; Zdzislaw, C. *J. Med. Chem.* **2000**, *43*, 3671. (c) Cruz, A.; Garduño, L.; Salazar, M.; Martínez, E.; Diaz, F.; Chamorro, G.; Tamariz, J. *Med. Chem. Res.* **2001**, *10*, 587.
8. (a) Cruz, A.; Garduño, L.; Salazar, M.; Martínez, E.; Jiménez-Vázquez, H. A.; Diaz, F.; Chamorro, G.; Tamariz, J. *Arzneim. Forsch. Drug Res.* **2001**, *51*, 535. (b) Chilmonczyk, Z.; Siluk, D.; Kaliszan, R.; Łozowicka, B.; Popławski, J.; Filipek, S. *Pure Appl. Chem.* **2001**, *73*, 1445.
9. (a) Gomez, C.; Chamorro, G.; Chav'ez, M. A.; Martinez, G.; Salazar, M.; Pages, N. *Plant Med. Phytother.* **1987**, *21*, 279. (b) Hernandez, A.; Lopez, M. L.; Chamorro, G.; Mendoza, F. T. *Planta Med.* **1993**, *59*, 121. (c) Bambang, W. N.; Brunhilde, S.; Victor, W.; Peter, P. *Phytochemistry* **1996**, *41*, 129. (d) Krause, M.; Ligneau, X.; Stark, H.; Garbarg, M.; Schwartz, J. C.; Schunack, W. *J. Med. Chem.* **1998**, *41*, 417. (e) Susana, A. Z.; Silvia, N. L.; Germán, D. P.; Ricardo, L. F.; Carina, B. S.; Lorena, M. F.; Fernando, A. G.; Ana, M. R.; Ricardo, D. E. *J. Nat. Prod.* **1999**, *62*, 1353.
10. (a) Sharma, P. K.; Dandiya, P. C. *Ind. J. Appl. Chem.* **1969**, *32*,

236. (b) Mori, I.; Nakachi, Y. *Tetrahedron Lett.* **1978**, *26*, 2297.
11. Buss, A. D.; Mason, R.; Warren, S. *Tetrahedron Lett.* **1983**, *24*, 5293.
12. Kabalka, G. W.; Li, N.; Tejedor, D.; Malladi, R. R.; Trotman, S. *J. Org. Chem.* **1999**, *64*, 3157.
13. Ohno, A.; Ohnishi, Y.; Tsuchihashi, G. *Tetrahedron Lett.* **1969**, *8*, 643.
14. (a) Miller, E. C.; Swanson, A. B.; Phillips, D. H.; Fletcher, T. L.; Liem, A.; Miller, J. A. *Cancer Res.* **1983**, *43*, 1124. (b) Kim, S. C.; Liem, A.; Stewart, B. C.; Miller, J. A. *Carcinogenesis* **1999**, *20*, 1303.
15. A large number of arylalkenes mostly phenylpropenes are found in high concentration (up to 90%) in many essential oil bearing plants as an isomeric mixture of three isomers namely *trans* (α), *cis* (β) and *gamma* (γ) isomers. Purification of these isomers into a pure single isomer by column chromatography is tedious.[16] Among three isomers, *cis*-arylalkenes are recently proved to be carcinogenic and toxic[14] which overall restrict the market potential of an essential oil rich in *cis*-isomer. Therefore, utilization of an isomeric mixture of arylalkenes via arylalkanes is an added benefit towards formation of useful products including (*E*)-arylalkenes (**3a**–**3g**) and arylalkanones (**3h**–**3j**).
16. Gates, B. D.; Swenton, J. S. *Tetrahedron Lett.* **1992**, *33*, 2127.
17. (a) Sen, A.; Lai, T. W. *Inorg. Chem.* **1981**, *20*, 4036. (b) Reddy, M. R.; Periasamy, M. *J. Organomet. Chem.* **1995**, *491*, 263. (c) Baxendale, I. R.; Lee, A. L.; Ley, S. V. *Synlett* **2002**, *3*, 516.
18. Yu, J.; Gaunt, M. J.; Spencer, J. B. *J. Org. Chem.* **2002**, *67*, 4627.
19. (a) Tamaru, Y.; Ochiai, H.; Ymada, Y.; Yoshida, Z. *Tetrahedron Lett.* **1983**, *24*, 3869. (b) Henk, J. S.; Frank, J. M. V.; Jim, A. F.; Joannes, B. P. A. W. *J. Nat. Prod.* **1998**, *61*, 1110.
20. (a) Soudagar, S. R.; Samant, S. D. *Ultrason. Sonochem.* **1995**, *2*, S15. (b) Thompson, L. H.; Doraiswamy, L. K. *Ind. Eng. Chem. Res.* **1999**, *38*, 1215. (c) Sinha, A. K.; Joshi, B. P.; Sharma, A.; Goel, H. C.; Prasad, J. *Nat. Prod. Res.* **2003**, *18*, 219.
21. (a) Sharma, A.; Joshi, B. P.; Sinha, A. K. *Chem. Lett.* **2003**, *32*, 1186.(b) Sinha, A. K.; Joshi, B. P.; Dogra, R. U.S. Patent 6566557, 2003. (c) Sinha, A. K.; Joshi, B. P.; Dogra, R. U.S. Patent 6590127, 2003.
22. Ram, S.; Ehrenkaufer, R. E. *Synthesis* **1988**, 91.
23. (a) Patra, A.; Mitra, A. K. *J. Nat. Prod.* **1981**, *44*, 668. (b) Sinha, A. K. U.S. Patent 6528041, 2003.
24. Fu, P. P.; Harvey, R. G. *Chem. Rev.* **1978**, *78*, 317.
25. (a) Walker, D.; Hiebert, J. D. *Chem. Rev.* **1967**, *67*, 153. (b) Lal, B.; Gidwani, R. M.; Reden, J.; de Souza, N. J. *Tetrahedron Lett.* **1984**, *25*, 2901. (c) Gonzalez, A. G.; Aguiar, Z. E.; Luis, J. G.; Ravelo, A. G. *J. Nat. Prod.* **1989**, *52*, 1231. (d) Ramdayal, F. D.; Kiemle, D. J.; Lalonde, R. T. *J. Org. Chem.* **1999**, *64*, 4607.
26. (a) Iliefski, T.; Li, S.; Lundquist, K. *Tetrahedron Lett.* **1998**, *39*, 2413. (b) Sinha, A. K.; Acharya, R.; Joshi, B. P. *J. Nat. Prod.* **2002**, *65*, 764.
27. Davidson, R. S.; Safdar, A.; Spencer, J. D.; Robinson, R. *Ultrasonics* **1987**, *25*, 35.
28. (a) Buckingham, J. *Dictionary of Organic Compounds*, Chapman & Hall, Mack Printing Company, Eastern Pennsylvania, New York, 1982. (b) Buckingham, J. *Dictionary of Natural Products*, Chapman & Hall Chemical Database, 2-6 Boundary Row, London SE18HN, 1994.