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Alternate Method for the Dimerization of 2-Benzylidene inden-1-one Derivatives: Synthesis of 1,3-Diaryl-1,3,3a,8a-tetrahydro-8*H*-spiro[cyclopenta[*a*]indene-2,2'-indene]-1',8(3'*H*)-diones

Hayreddin GEZEGEN

Department of Nutrition and Dietetics, Faculty of Health Sciences, Cumhuriyet University, Sivas, Turkey

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Abstract: In the present study, a series of 1,3-diaryl-1,3,3a,8a-tetrahydro-8*H*-spiro[cyclopenta[*a*]indene-2,2'-indene]-1',8(3'*H*)-dione derivatives (**4a-h**) were synthesized by KO*t*-Bu catalyzed dimerization of 2-benzylidene inden-1-one derivatives. The structures of obtained novel spiro-dimeric compounds were characterized using the spectroscopic methods (^{1}H, ^{13}C, 2D NMR and IR).

Keywords: 2-Benzylidene inden-1-one, dimerization, spirocyclic-dimer, chalcone like compound.

2-Benziliden inden-1-on Türevlerinin Dimerleşmesi için Alternatif Yöntem: 1,3-Diaril-l,3,3a,8a-tetrahidro-8*H*-spiro[siklopenta[*a*]inden-2,2'-inden]-1',8(3'*H*)-dionların Sentezi

Özet: Bu çalışmada, bir seri 1,3-Diaril-l,3,3a,8a-tetrahidro-8*H*-spiro[siklopenta[*a*]inden-2,2'-inden]-1',8(3'*H*)-dion türevi (**4a-h**), 2-benziliden inden-1-on türevlerinin KO*t*-Bu katalizli dimerleşmesi yolu ile sentezlendi. Elde edilen yeni spiro-dimerik bileşiklerin yapıları spektroskopik yöntemlerle (^{1}H, ^{13}C, 2D NMR ve IR) karakterize edildi.

***Anahtar Kelimeler*:** 2-Benziliden inden-1-on, dimerleşme, spirohalkalı-dimer, kalkon tipi bileşik.

1. INTRODUCTION

Chalcones and chalcone like compounds are important compounds having a wide spectrum in terms of biological activity and can be easily synthesized in high yields [1]. Besides the biological activity they are chemically very active compounds because they contain α,β-unsaturated carbonyl system on structures. Therefore, many heterocyclic and polyfunctional compounds can be synthesized easily starting from chalcones or chalcone like compounds [2]. 2-Benzylidene inden-1-one derivatives are chalcone type compounds and their bioactive potentials are quite high. They draw attention due to have bioactive properties such as monoamine oxidase inhibitors [3], AChE inhibitors [4], antiproliferative [5], anticancer [6] antioxidant activity [7] and Alzheimer's treatment [8]. In addition, they are valuable compounds from the synthetic point of view because used as starting material in the synthesis of important compounds such as indeno pyrazole [9], indeno pyrimidine [10] and indeno pyridine derivatives [11,12]. 2-Benzylideneinden-1-one derivatives, unlike chalcones, contain a methylene unit in structures so they are given dimerization reaction in basic medium and

* Corresponding author. *Email address:* *gezegenh@cumhuriyet.edu.tr*

convert into spiro-dimeric products [13]. In studies on dimerization reactions of the 2-benzylidene inden-1-one derivatives in the literature, it have been reported to synthesized various spiro-dimeric stereoisomers using different base-solvent systems such as $NaHCO_3$/DMF, guanidine carbonate/DMF, Cs_2CO_3/CH_3CN [14-16], KOH/EtOH, K_2CO_3/EtOH, NaOEt/EtOH [17] and NaOEt/THF [18].

This study reports the synthesis of spiro-dimeric products of 2-benzylidene inden-1-one derivatives in the mild conditions in the presence of catalytic amount of potassium-tertiary-butoxide (KO*t*-Bu) in dimethylsulfoxide (DMSO). This reaction occurs in short reaction time and result in high yields so, this method is easy and effective in terms of applicability for synthesis of spiro-dimeric products of 2-benzylidene inden-1-one derivatives.

2. EXPERIMENTAL

Melting points were measured on an Electrothermal 9100 apparatus. IR spectra (KBr disc) were recorded on a Jasco FT/IR-430 spectrometer. ^{1}H and ^{13}C NMR spectra were recorded on a Bruker Avance DPX-400 instrument and Agilent 600 MHz Premium COMPACT NMR instrument in $CDCl_3$ (for **4b-h**) and DMSO-d_6 (for **4a**); δ in ppm rel. to Me_4Si (δ 0.00) for ^{1}H NMR, $CDCl_3$ (δ 77.0) and DMSO-d_6 (δ 39.5) for ^{13}C-NMR spectra as internal standards, *J* in Hz. NOESY spectra of **4a** was recorded on Bruker 300 Mhz Ultrashield instrument in DMSO-d_6. The multiplicities of the signals in the ^{1}H-NMR spectra are abbreviated by s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet), br (broad), and combinations thereof.

2.1. General Procedure for the Synthesis of 2-benzylidene inden-1-one derivatives (3a-h):

The synthesis of 2-benzylidene inden-1-one derivatives was carried out according to previous article [19].

2.2. General Procedure for the Synthesis of 1,3-diaryl-1,3,3a,8a-tetrahydro-8*H*-spiro[cyclopenta[*a*]indene-2,2'-indene]-1',8(3'*H*)-dione (4a-h):

To a solution of 2-benzylideneinden-1-one derivative (1 mmol) (**3a-h**) in DMSO (5 mL) at 50 °C was added KO*t*-Bu (10% mol) and stirred for 3 h. After the reaction is complete, the mixture was acidified with diluted HCl (10% 5 mL) and extracted with CH_2Cl_2 (20 mL) and dried over Na_2SO_4. After the solvent removed in vacua, the product was crystalized with EtOH.

(1*RS*,2*SR*,3*SR*,3a*RS*,8a*RS*)-1,3-di-*p*-tolyl-1,3,3a,8a-tetrahydro-8*H*-spiro[cyclopenta[*a*]indene-2,2'-indene]-1',8(3'*H*)-dione (**4a**):

White solid; yield 75%; m.p. 156-159 °C. IR (KBr, cm^{-1}) 3087, 3020, 2949, 2915, 2887, 1686, 1621, 1601, 1581, 1510, 1465, 1328, 1295, 1270, 1184, 1099, 1087, 954, 817, 740, 522. ^{1}H NMR (400 MHz, DMSO-d_6) δ 7.67 (d, *J* = 7.6 Hz, 1H), 7.54 (t, *J* = 7.4 Hz, 1H), 7.48-7.43 (m, 2H), 7.32 (t, *J* = 7.4 Hz, 1H), 7.21 (d, *J* = 7.7 Hz, 2H), 7.19-7.10 (m, 4H), 7.05-6.94 (m, 5H), 4.72 (t, *J* = 9.7 Hz, 1H), 4.10 (t, *J* = 9.6 Hz, 1H), 3.79 (d, *J* = 10.6 Hz, 1H), 3.47 (d, *J* = 11.0 Hz, 1H), 3.12 (d, *J* = 17.9 Hz, 1H), 3.01 (d, *J* = 17.9 Hz, 1H) 2.13 (s, 3H), 2.12 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 207.73, 206.61, 156.48, 153.42, 137.06, 136.84, 136.47, 135.88, 135.71, 135.57, 134.52, 133.75, 129.43 (2C), 129.15 (2C), 128.88, 128.77 (2C), 128.52 (2C), 127.77, 126.60, 125.57, 124.34, 123.30, 69.69, 59.90, 54.29, 53.22, 46.04, 29.40, 20.94, 20.90.

(1*RS*,2*SR*,3*SR*,3a*RS*,8a*RS*)-1,3-bis(4-methoxyphenyl)-1,3,3a,8a-tetrahydro-8*H*-spiro[cyclopenta[*a*]indene-2,2'-indene]-1',8(3'*H*)-dione (**4b**):

White solid; yield 70%; m.p. 173-176 °C. IR (KBr, cm^{-1}) 3069, 3032, 2953, 2927, 2833, 1713, 1698, 1609, 1582, 1512, 1465, 1441, 1328, 1283, 1257, 1176, 1096, 1034, 1012, 953, 916, 822,

752, 570. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.75 (d, J = 7.6 Hz, 1H), 7.54 (d, J = 7.6 Hz, 1H), 7.44 (t, J = 7.4 Hz, 1H), 7.38 (t, J = 7.4 Hz, 1H), 7.25 (t, J = 7.4 Hz, 1H), 7.20 (d, J = 8.3 Hz, 2H), 7.16 (d, J = 8.4 Hz, 2H), 7.11 (t, J = 7.4 Hz, 1H), 7.07 (d, J = 7.6 Hz, 1H), 6.98 (d, J = 7.7 Hz, 1H), 6.71 (d, J = 8.4 Hz, 2H), 6.66 (d, J = 8.4 Hz, 2H), 4.47 (t, J = 9.6 Hz, 1H), 4.02 (d, J = 10.9 Hz, 1H), 3.86 – 3.81 (m, 1H), 3.77 (d, J = 10.7 Hz, 1H), 3.69 (s, 3H), 3.67 (s, 3H), 3.02 (dd, J = 36.5, 17.0 Hz, 2H). ^{13}C NMR (150 MHz, $CDCl_3$) δ 207.99, 205.68, 158.62, 158.43, 155.88, 152.99, 137.28, 135.75, 135.07, 134.68, 129.44 (2C), 129.15 (2C), 128.79, 128.58, 128.17, 126.96, 125.82, 125.22, 124.45, 123.33, 113.69 (2C), 113.59 (2C), 70.31, 58.49, 55.09 (2C), 53.53, 53.14, 46.28, 29.49.

(1*RS*,2*SR*,3*SR*,3a*RS*,8a*RS*)-1,3-bis(4-fluorophenyl)-1,3,3a,8a-tetrahydro-8*H*-spiro[cyclopenta[*a*]indene-2,2'-indene]-1',8(3'*H*)-dione (**4c**):

Colourless crystal; yield 89%; m.p. 201-204 °C. IR (KBr, cm^{-1}) 3069, 3045, 2975, 2938, 2893, 1698, 1603, 1510, 1464, 1434, 1329, 1285, 1226, 1164, 1088, 1045, 1015, 919, 845, 794, 750, 622, 546. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.76 (d, J = 7.6 Hz, 1H), 7.54 (d, J = 7.6 Hz, 1H), 7.46 (t, J = 7.4 Hz, 1H), 7.40 (t, J = 7.4 Hz, 1H), 7.30 – 7.25 (m, 3H), 7.24 – 7.19 (m, 2H), 7.13 (t, J = 7.4 Hz, 1H), 7.04 (d, J = 7.6 Hz, 1H), 6.99 (d, J = 7.6 Hz, 1H), 6.87 (t, J = 8.3 Hz, 2H), 6.82 (t, J = 8.4 Hz, 2H), 4.49 (t, J = 9.6 Hz, 1H), 4.04 (d, J = 10.9 Hz, 1H), 3.85 (t, J = 9.7 Hz, 1H), 3.79 (d, J = 10.6 Hz, 1H), 3.00 (dd, J = 41.8, 17.1 Hz, 2H). ^{13}C NMR (150 MHz, $CDCl_3$) δ 207.45, 205.35, 161.96 (d, J = 246.5 Hz), 161.82 (d, J = 245.9 Hz), 155.44, 152.56, 137.02, 135.61, 135.33, 135.08, 132.31 (d, J = 3.0 Hz), 132.15 (d, J = 3.2 Hz), 129.90 (d, J = 7.9 Hz, 2C), 129.65 (d, J = 8.0 Hz, 2C), 128.44, 127.30, 125.81, 125.14, 124.60, 123.44, 115.33 (d, J = 21.2 Hz, 2C), 115.09 (d, J = 21.3 Hz, 2C), 70.08, 58.40, 53.37, 53.08, 46.26, 29.36.

(1*RS*,2*SR*,3*SR*,3a*RS*,8a*RS*)-1,3-bis(4-chlorophenyl)-1,3,3a,8a-tetrahydro-8*H*-spiro[cyclopenta[*a*]indene-2,2'-indene]-1',8(3'*H*)-dione (**4d**):

White solid; yield 87%; m.p. 250-253 °C. IR (KBr, cm^{-1}) 3080, 3049, 3031, 2938, 2885, 1702, 1599, 1513, 1492, 1467, 1424, 1329, 1280, 1239, 1212, 1153, 1088, 1011, 961, 919, 815, 766, 572, 511. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 – 7.74 (m, 1H), 7.58 (d, J = 7.7 Hz, 1H), 7.47 (td, J = 7.4, 1.4 Hz, 1H), 7.41 (t, J = 7.4 Hz, 1H), 7.34 – 7.28 (m, 1H), 7.26 (d, J = 8.5 Hz, 2H), 7.21 (d, J = 8.5 Hz, 2H), 7.19 – 7.14 (m, 3H), 7.14 – 7.09 (m, 2H), 7.06 (d, J = 7.5 Hz, 1H), 7.02 (d, J = 7.7 Hz, 1H), 4.60 – 4.46 (m, 1H), 4.07 (d, J = 10.9 Hz, 1H), 3.89 (dd, J = 10.7, 8.7 Hz, 1H), 3.81 (d, J = 10.7 Hz, 1H), 3.06 (d, J = 17.2 Hz, 1H), 2.98 (d, J = 17.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 207.30, 205.29, 155.35, 152.53, 136.94, 135.62, 135.45, 135.31, 135.17, 134.93, 133.34, 132.99, 129.78 (2C), 129.54 (2C), 128.66 (2C), 128.56, 128.45 (2C), 127.50, 125.98, 125.23, 124.64, 123.51, 69.89, 58.58, 53.52, 52.92, 46.07, 29.41.

(1*RS*,2*SR*,3*SR*,3a*RS*,8a*RS*)-1,3-bis(4-bromophenyl)-1,3,3a,8a-tetrahydro-8*H*-spiro[cyclopenta[*a*]indene-2,2'-indene]-1',8(3'*H*)-dione (**4e**):

White solid; yield 85%; m.p. 234-237 °C. IR (KBr, cm^{-1}) 3076, 3046, 3027, 2949, 2937, 2883, 1698, 1598, 1489, 1467, 1423, 1329, 1278, 1239, 1152, 1074, 1005, 959, 918, 839, 812, 765, 754, 711, 678, 572, 507. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.76 (d, J = 7.3 Hz, 1H), 7.58 (d, J = 7.6 Hz, 1H), 7.46 (td, J = 7.4, 1.3 Hz, 1H), 7.42 – 7.37 (m, 1H), 7.35 – 7.29 (m, 3H), 7.26 (d, J = 8.5 Hz, 2H), 7.20 (d, J = 8.5 Hz, 2H), 7.18 – 7.12 (m, 3H), 7.05 (d, J = 7.4 Hz, 1H), 7.01 (d, J = 7.7 Hz, 1H), 4.58 – 4.47 (m, 1H), 4.05 (d, J = 10.8 Hz, 1H), 3.88 (dd, J = 10.8, 8.6 Hz, 1H), 3.79 (d, J = 10.7 Hz, 1H), 3.06 (d, J = 17.2 Hz, 1H), 2.97 (d, J = 17.3 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 207.26, 205.28, 155.32, 152.51, 136.91, 135.71, 135.61, 135.47, 135.44, 135.36, 131.62 (2C), 131.39 (2C), 130.14 (2C), 129.90 (2C), 128.58, 127.54, 126.02, 125.24, 124.64, 123.53,

121.55, 121.24, 69.76, 58.65, 53.58, 52.87, 46.02, 29.43.

(1*RS*,2*SR*,3*SR*,3a*RS*,8a*RS*)-1,3-diphenyl-1,3,3a,8a-tetrahydro-8*H*-spiro[cyclopenta[*a*]indene-2,2'-indene]-1',8(3'*H*)-dione (**4f**):

White solid; yield 81% (79% [18]); m.p. 238-240 °C (236-237 °C [18]). IR (KBr, cm^{-1}) 3085, 3057, 3027, 2939, 2887, 1698, 1602, 1585, 1496, 1466, 1374, 1337, 1282, 1240, 1208, 1152, 1096, 1012, 911, 857, 757, 730, 700, 574. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78 (d, J = 7.5 Hz, 1H), 7.58 (d, J = 7.6 Hz, 1H), 7.49 (td, J = 7.4, 1.1 Hz, 1H), 7.43 (t, J = 7.3 Hz, 1H), 7.36 – 7.30 (m, 1H), 7.29 – 7.24 (m, 3H), 7.23 – 7.16 (m, 6H), 7.13 (d, J = 8.5 Hz, 2H), 7.07 (d, J = 7.5 Hz, 1H), 7.03 (d, J = 7.7 Hz, 1H), 4.52 (t, J = 10.1 Hz, 1H), 4.06 (d, J = 10.9 Hz, 1H), 3.88 (dd, J = 10.8, 8.7 Hz, 1H), 3.81 (d, J = 10.7 Hz, 1H), 3.05 (d, J = 17.2 Hz, 1H), 2.97 (d, J = 17.1 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 207.27, 205.23, 155.33, 152.50, 136.95, 135.62, 135.44, 135.29, 135.11, 134.94, 133.34, 133.01, 129.76 (2C), 129.52 (2C), 128.66 (2C), 128.56, 128.45 (2C), 127.50, 125.95, 125.20, 124.68, 123.53, 69.89, 58.55, 53.52, 52.90, 46.07, 29.40.

(1*RS*,2*SR*,3*SR*,3a*RS*,8a*RS*)-1,3-di(furan-2-yl)-1,3,3a,8a-tetrahydro-8*H*-spiro[cyclopenta[*a*]indene-2,2'-indene]-1',8(3'*H*)-dione (**4g**):

White solid; yield 80% (48% [18]); m.p. 192-195 °C (196-197 °C [18]). IR (KBr, cm^{-1}) 3129, 3116, 3068, 3033, 2927, 2903, 2891, 2849, 1703, 1603, 1590, 1503, 1466, 1433, 1336, 1284, 1237, 1145, 1097, 1070, 1011, 958, 913, 891, 809, 750, 674, 598. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.76 (d, J = 7.6 Hz, 1H), 7.71 (d, J = 7.6 Hz, 1H), 7.52 (t, J = 7.4 Hz, 1H), 7.40 (t, J = 7.5 Hz, 2H), 7.30 – 7.11 (m, 4H), 7.01 (s, 1H), 6.31 – 6.25 (m, 1H), 6.22 – 6.15 (m, 2H), 6.16 – 6.11 (m, 1H), 4.45 (t, J = 9.5 Hz, 1H), 3.93 (d, J = 10.8 Hz, 1H), 3.83 – 3.65 (m, 2H), 3.15 (d, J = 17.2 Hz, 1H), 3.04 (d, J = 17.3 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 206.02, 204.85, 155.08, 152.84, 152.00, 151.76, 142.37, 141.98, 136.51, 135.63, 135.53, 134.81, 128.54, 127.19, 126.03, 125.64, 124.47, 123.82, 110.20, 110.14, 108.17, 108.06, 68.21, 53.14, 52.65, 47.86, 46.32, 31.11.

(1*RS*,2*SR*,3*SR*,3a*RS*,8a*RS*)-1,3-di(thiophen-2-yl)-1,3,3a,8a-tetrahydro-8*H*-spiro[cyclopenta[*a*]indene-2,2'-indene]-1',8(3'*H*)-dione (**4h**):

White solid; yield 86% (70% [18]); m.p. 250-253 °C (254-255 °C [18]). IR (KBr, cm^{-1}) 3109, 3069, 3035, 2937, 2913, 2884, 2839, 1703, 1601, 1586, 1533, 1465, 1430, 1332, 1283, 1237, 1210, 1152, 1096, 1045, 1011, 950, 916, 853, 763, 716, 671, 626, 503. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 (d, J = 7.6 Hz, 1H), 7.68 (d, J = 7.6 Hz, 1H), 7.51 (t, J = 7.4 Hz, 1H), 7.43 (t, J = 7.4 Hz, 1H), 7.38 (t, J = 7.4 Hz, 1H), 7.27 (d, J = 7.7 Hz, 1H), 7.23 (t, J = 7.4 Hz, 1H), 7.15 (d, J = 7.7 Hz, 1H), 7.09 (d, J = 5.0 Hz, 1H), 7.01 (d, J = 5.1 Hz, 1H), 6.95 (d, J = 3.5 Hz, 1H), 6.89 (d, J = 3.4 Hz, 1H), 6.86 – 6.78 (m, 2H), 4.49 – 4.34 (m, 1H), 4.24 (d, J = 10.8 Hz, 1H), 4.02 (d, J = 10.5 Hz, 1H), 3.79 (dd, J = 10.8, 8.6 Hz, 1H), 3.27 (d, J = 17.3 Hz, 1H), 3.17 (d, J = 17.3 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 206.74, 204.45, 154.77, 153.49, 140.47, 140.04, 137.27, 135.65, 135.48, 135.01, 128.66, 127.34, 126.99, 126.77, 126.17, 126.13, 126.07, 125.42, 124.61, 124.47, 124.20, 123.67, 70.02, 55.42, 54.58, 49.49, 49.33, 30.62.

3. RESULTS and DISCUSSION

Herein, we report a novel procedure for the synthesis of 1,3-diaryl-1,3,3a,8a-tetrahydro-8*H*-spiro[cyclopenta[*a*]indene-2,2'-indene]-1',8(3'*H*)-dione derivatives (**4a-h**) that have five stereogenic centers. The 2-benzylidene inden-1-one derivatives **3a-h** were prepared by reaction of 1-indanone (**1**) with aromatic aldehydes (**2a-h**) in the presence of NaOH in EtOH at room temperature [19]. Spiro-dimeric compounds (**4a-h**) were synthesized by treatment of **3a-h** with KO*t*-Bu in DMSO at 50 °C. The crude product at the end of the reaction was subjected to crystallization in EtOH and only one stereoisomer was obtained in high yields (70-89%) (Figure 1, Table 2).

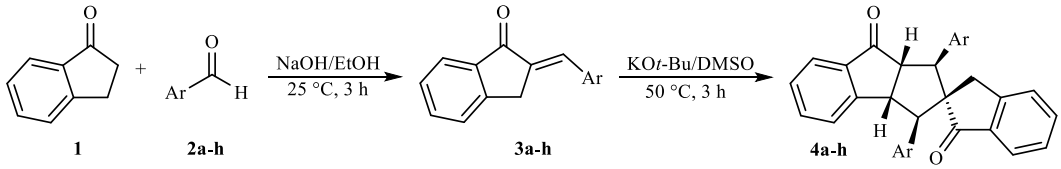


Figure 1. Synthesis of spiro-dimeric products.

The structures of **4a-h** were determined by spectroscopic studies (^{1}H-, ^{13}C-, 2D-NMR and IR) and literature data [18]. The relative stereochemistry of **4a** was established by COSY, HETCOR, HMBC and NOESY experiments, which confirmed the relative configuration between all the neighboring substituents (Figure 2, Figure 3 and Figure 4).

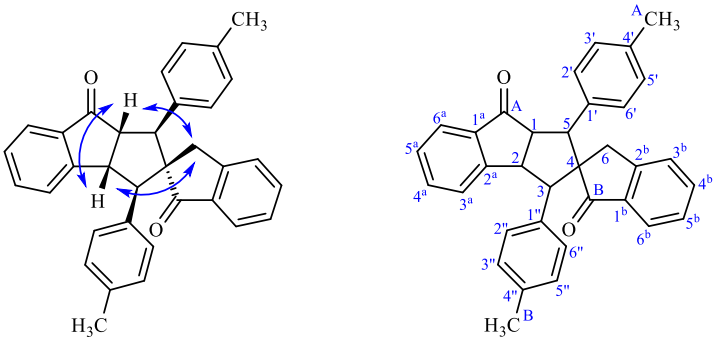


Figure 2. Selected NOESY interactions of **4a** and numbering of carbons.

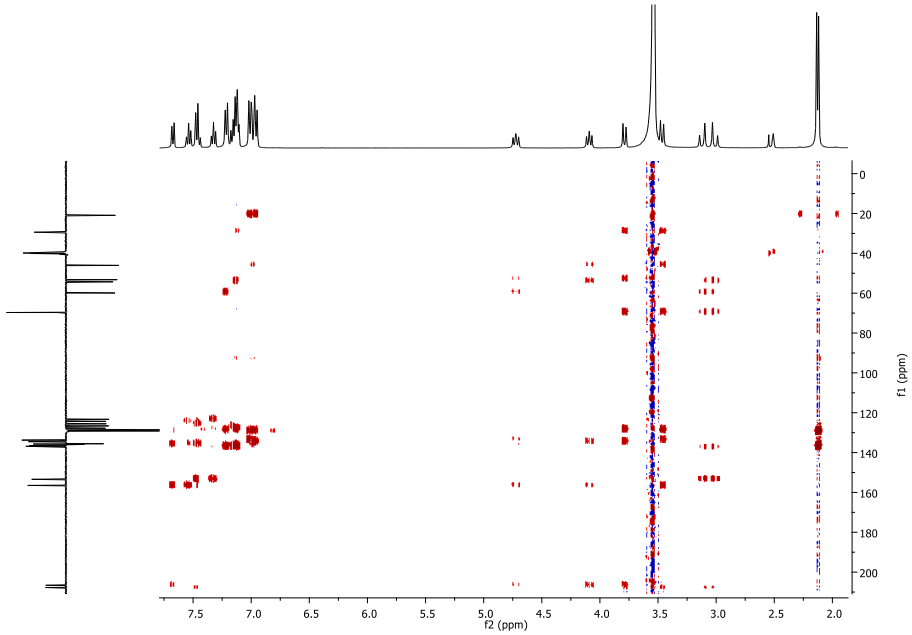


Figure 3. HMBC spectrum of **4a.**

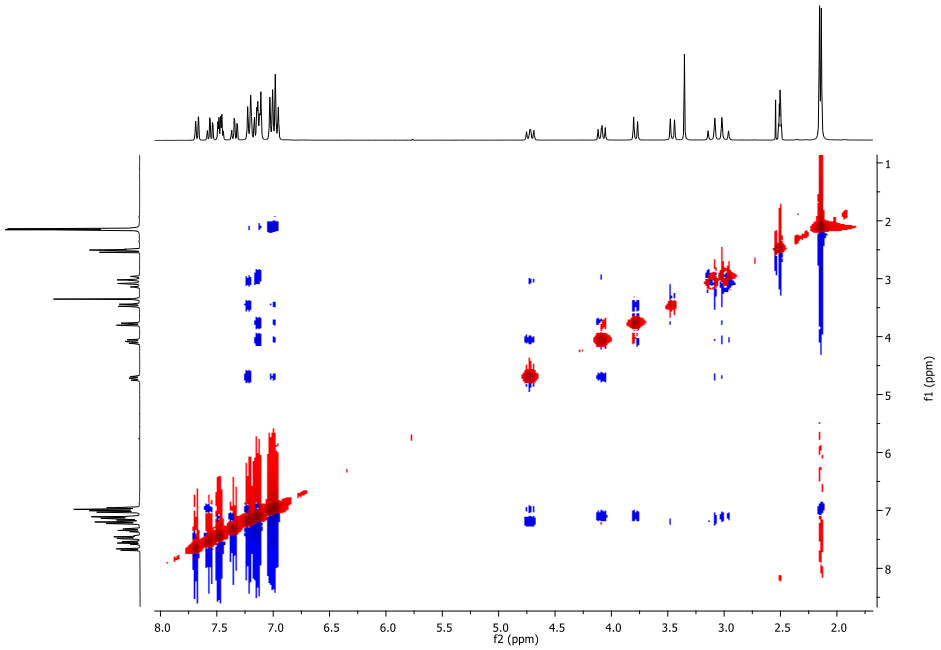


Figure 4. NOESY spectrum of **4a.**

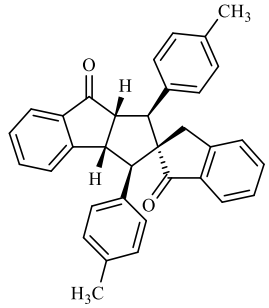
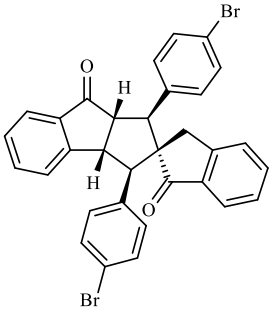
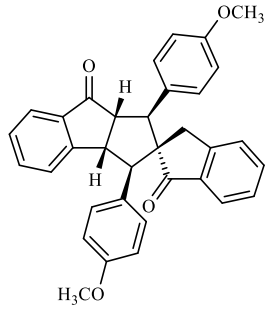
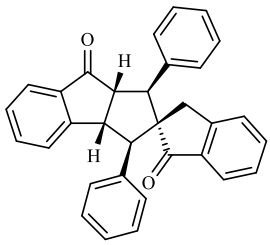
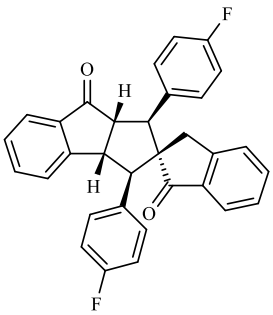
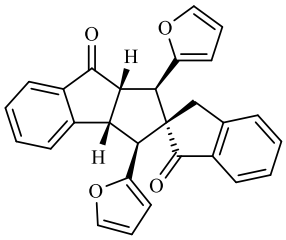
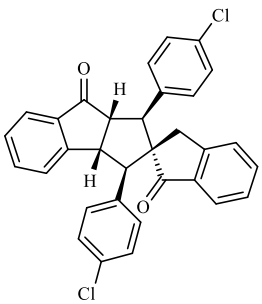
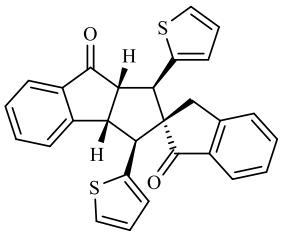
The full analysis of HETCOR and HMBC spectra of **4a** confirmed the spiro-dimeric structure. In the ^{1}H-NMR spectrum of **4a** the protons of H-C(1) and H-C(2) gave a triplet at δ 4.72 (J = 9.7 Hz) and 4.10 (J = 9.6 Hz) ppm respectively. The protons of H-C(5) and H-C(3) gave a doublet at δ 3.47 (J = 11.0 Hz) and 3.79 (J = 10.6 Hz) ppm respectively. The methylenic protons of H_2-C(6) gave an AB system, while the A part of the AB system is shown as a doublet at δ 3.12 (J = 17.9 Hz) and that of part B as a doublet at δ 3.01 (*d*, J = 17.9) ppm. In addition, the ^{13}C-NMR spectrum of **4a** showed two carbonyl signals at 207.7 and 206.6 ppm. Other aliphatic and aromatic carbon signals are in harmony with the structure (Figure 4, Table 1).

Table 1. ^{1}H and ^{13}C NMR (DMSO-d_6) data of **4a**, δ (ppm), J (Hz).

Position	HETCOR (H → C)		HMBC (H → C)	
	δ(H)	δ(C)	^{2}J	^{3}J
1	4.72 (*t*, J = 9.7)	46.0	C(2), C(5), C(^{A}C=O)	C(1'), C(2^{a})
2	4.10 (*t*, J = 9.6)	53.2	C(1), C(3), C(2^{a})	C(1''), C(^{A}C=O)
3	3.79 (*d*, J = 10.6)	54.3	C(2), C(4), C(1'')	C(6), C(2''), C(6''), C(^{A}C=O), C(^{B}C=O)
4	-	69.7		
5	3.47 (*d*, J = 11.0)	59.9	C(1), C(4), C(1')	C(6), C(2'),C(6'), C(^{B}C=O)
6	3.12 (*d*, J = 17.9) 3.01 (*d*, J = 17.9)	29.4	C(4), C(2^{b})	C(3), C(5), C(1^{b}), C(^{B}C=O)
1^{a}	-	135.7		
2^{a}	-	156.5		
3^{a}	7.54 (t, J = 7.4)	135.8	C(2^{a})	C(1^{a})
4^{a}	7.05-6.94 (m)	125.5	C(3^{a}), C(5^{a})	
5^{a}	7.46 (t, J = 7.8)	128.8	C(4^{a}), C(6^{a})	C(1^{a}), C(3^{a})
6^{a}	7.67 (d, J = 7.6)	124.3	C(1^{a}), C(5^{a})	C(2^{a}) C(^{A}C=O)
1^{b}	-	137.0		
2^{b}	-	153.4		
3^{b}	7.32 (t, J = 7.4)	135.5	C(2^{b})	C(1^{b}), C(5^{b})
4^{b}	7.19-7.10 (m)	126.6	C(3^{b}), C(5^{b})	
5^{b}	7.19-7.10 (m)	127.7	C(4^{b})	C(1^{b})
6^{b}	7.48-7.43 (m)	123.3		C(2^{b}), C(4^{b}) C(^{B}C=O)
1'	-	133.7		
2'	7.21 (d, J = 7.7)	128.7		C(5), C(4'), C(6')

3’	7.05-6.94 (m)	129.4		C(1’), C(5’), C(^{A}CH$_3$)
4’	-	136.8		
5’	7.05-6.94 (m)	129.4		C(1’), C(3’), C(^{A}CH$_3$)
6’	7.21 (d, *J* = 7.7)	128.7		C(5), C(2’), C(4’)
1’’	-	134.5		
2’’	7.19-7.10 (m)	128.5		C(3), C(4’’), C(6’’)
3’’	7.05-6.94 (m)	129.1		C(1’’), C(5’’), C(^{B}CH$_3$)
4’’	-	136.4		
5’’	7.05-6.94 (m)	129.1		C(1’’), C(3’’), C(^{B}CH$_3$)
6’’	7.19-7.10 (m)	128.5		C(3), C(2’’), C(4’’)
^{A}C=O	-	206.6		
^{B}C=O	-	207.7		
^{A}CH$_3$	2.11 (s)	20.8	C(4’)	C(3’), C(5’)
^{B}CH$_3$	2.13 (s)	20.9	C(4’’)	C(3’’), C(5’’)

Table 2. Synthesized spiro-dimers **4a-h.**

Entry	Spiro-dimer	Yield (%)	Entry	Spiro-dimer	Yield (%), (Lit.)
1	 **4a**	75	5	 **4e**	85
2	 **4b**	70	6	 **4f**	81 (79) [18]
3	 **4c**	89	7	 **4g**	80 (48) [18]
4	 **4d**	87	8	 **4h**	86 (70) [18]

4. CONCLUSION

In summary, five new (**4a-e**) and three known (**4f-h**) 1,3-diaryl-1,3,3a,8a-tetrahydro-8*H*-spiro[cyclopenta[*a*]indene-2,2'-indene]-1',8(3'*H*)-dione derivatives were synthesized by KO*t*-Bu (10%) catalysis in high yields from 2-benzylidene inden-1-one derivatives. As a result of the reaction carried out, one stereoisomer was obtained in high yields (70-89%). The relative stereochemistry of the synthesized spirocyclic-dimers were determined using 2D-NMR techniques. The present method has some advantages such as high yields of the products, atom economy, short reaction time, and simple workup and purification.

REFERENCES

[1]. P. Singh, A. Anand, V. Kumar, *Europ. J. Med. Chem.* 2014, 85, 758-777.

[2]. B. Sharifzadeh, N. O. Mahmoodi, M. Mamaghani, K. Tabatabaeian, A. S. Chirani, I. Nikokar, *Bioorg. Med. Chem. Lett.* 2013, 23, 548-551.

[3]. M. S. Nel, A. Petzer, J. P. Petzer, L. J. Legoabe, *Bioorg. Chem.* 2016, 69, 20-28.

[4]. S. Rizzo, M. Bartolini, L. Ceccarini, L. Piazzi, S. Gobbi, A. Cavalli, M. Recanatini, V. Andrisano and A. Rampa, *Bioorg. Med. Chem.* 2010, 18, 1749-1760.

[5]. G. A. Tunbridge, J. Oram, L. Caggiano, *Med. Chem. Commun.* 2013, 4, 1452-1456.

[6]. Singh, K. Fatima, A. Singh, A. Behl, M. J. Mintoo, M. Hasanain, R. Ashraf, S. Luqman, K. Shanker, D. M. Mondhe, J. Sarkar, D. Chanda, A. S. Negi. *Europ. J. Pharm. Sci.*, 2015, 76, 57-67.

[7]. H. Aichaoui, F. Guenadil, C. N. Kapanda, D. M. Lambert, C. R. McCurdy, J. H. Poupaert, *Med. Chem. Res.* 2009, 18, 467-476.

[8]. Saxena, U. Faridi, S. Srivastava, J. Kumar, M. Darokar, S. Luqman, S. Chanotiya, V. Krishna, S. Negi, S. Khanuja, *Bioorg. Med. Chem. Lett.* 2008, 18, 3914-3918.

[9]. S. A. F. Rostom, I. M. El-Ashmawy, H. A. Abd El Razik, M. H. Badr, H. M. A. Ashour, *Bioorg. Med. Chem.* 2009, 17, 882-895.

[10]. K. V. Diveshkumar, S. Sakrikar, S. Harikrishna, V. Dhamodharan, P. I. Pradeepkumar, *Chem. Med. Chem.* 2014, 9, 2754-2765.

[11]. T. M. Kadayat, C. Park, K.-Y. Jun, T. B. T. Magar, G. Bist, H. Y. Yoo, Y. Kwon, E.-S. Lee, *Europ. J. Med. Chem.* 2015, 90, 302-314.

[12]. Ş. Öztürk, M. B. Gürdere, H. Gezegen, M. Ceylan, Y. Budak, *Org. Commun*. 2016, 9,125-132.

[13]. G. Narang, D. P. Jindal, B. Jit, R. Bansal, *Helv. Chim. Acta* 2006, 89, 258-264.

[14]. C. Berthelette, C. McCooye, Y. Leblanc, L. A. Trimble, *J. Org. Chem.* 1997, 62, 4339-4342.

[15]. Y. Leblanc, C. Dufresne, R. Dhawan, J. Ollerenshaw, A. Littke, L. A. Trimble, N. N. Tsou, *Can. J. Chem.* 2000, 78, 784-790.

[16]. W. Wendelin, K. Schermanz, E. Breitmaier, *Monatsh. Chem.* 1988, 119, 355-365.

[17]. W. J. Houlihan, M. J. Shapiro, J. A. Chin, *J. Org. Chem.* 1997, 62, 1529-1531.

[18]. P. Camps, L. R. Domingo, X. Formosa, C. Galdeano, D. Gonzalez, D. Munoz-Torrero, S. Segales, M. Font-Bardia, X. Solans, *J. Org. Chem.* 2006, 71, 3464-3471.

[19]. İ. Karaman, H. Gezegen, M. B. Gürdere, A. Dingil, M. Ceylan, Chem. Biodiv. 2010, 7, 400-408.