Supporting Information

Design and synthesis of highly oxygenated furo[3,2-c]pyran-4-ones and furo[3,2-c]chromen-4-ones scaffold as potential anticancer and antimicrobial agent

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Experimental

Synthesis of highly oxygenated furo[3,2-c]pyran-4-one (4, 5, 8 and 9)

Dehydroacetic acid (1, 1 mmol) or its chalcone (4, 1 mmol) was dissolved in acetonitrile (15 mL) and refluxed for 3 hours after addition of \( \alpha \)-bromoketone (2, 1 mmol) and potassium carbonate (K\(_2\)CO\(_3\)) (3 mmol). The reaction was monitored by TLC using hexane from petroleum-ethylacetate (9:1). After completion, the reaction mixture was cooled to room temperature and water was added to precipitate the desired product (4, 5). The precipitates were filtered, washed with water and crystallized from ethanol. Similarly, furo[3,2-c]chromen-4-ones (8, 9) were synthesized using the above protocols.

2-Benzoyl-3,6-dimethyl-4H-furo[3,2-c]pyran-4-one (4a)

Colour: White, m.p. 142\(^°\)C, yield 98\%, I.R. (KBr, cm\(^{-1}\)): 1756(-O-C=O), 1622(-C=O); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \): 7.93 (m, 2H, C\(_2\)/C\(_6\)-H), 7.60 (m, 1H, C\(_4\)-H), 7.50 (m, 2H, C\(_3\)/C\(_5\)-H), 6.43 (d, 1H, C\(_7\)-H, J=0.9 Hz), 2.66 (s, 3H, C\(_3\)-CH\(_3\)), 2.37 (s, 3H, C\(_6\)-CH\(_3\)); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): 184.00 (-C=O), 163.27 (C-1a), 161.92 (C-6), 159.27 (C-2), 147.98 (C-4), 137.40 (C-1'), 132.77 (C-3), 131.37 (C-4'), 129.34 (C-2'/C-6'), 128.44 (C-3'/C-5'), 109.98 (C-3a), 95.63 (C-7), 20.58 (C-6- CH\(_3\)), 10.88 (C-3-CH\(_3\)); HRMS: m/z(M\(^+\)) calcd. for C\(_{16}\)H\(_{12}\)O\(_4\): 268.0736, found: 269.0889(M\(^+\)+H).
6-Dimethyl-2-(4-methylbenzoyl)-4H-furo[3,2-c]pyran-4-one (4b)
Colour: White, m.p. 205°C, yield 98%, I.R. (KBr,cm⁻¹): 1736 (O=C=O), 1624 (C=O); ¹H NMR (400 MHz, CDCl₃) δ : 7.85 (d, 2H, C₂/C₆-H, J=8.4 Hz), 7.29 (d, 2H, C₃/C₅-H, J=8.0 Hz), 6.42 (d, 1H, C7-H, J=0.8 Hz), 2.66 (s, 3H, C₃-CH₃), 2.45 (s, 3H, C₆-CH₃), 2.37 (s, 3H, C₄-CH₃); ¹³C NMR (100 MHz, CDCl₃): 183.69 (C=O), 163.09 (C-1a), 161.80 (C-6), 159.34 (C-2), 148.14 (C-4), 143.71 (C-4'), 134.75 (C-1'), 130.88 (C-3), 129.55 (C-2'/C-6'), 129.15 (C-3'/C-5'), 109.95 (C-3a), 95.65 (C-7), 21.73 (C-4'-CH₃), 20.57 (C-6-CH₃), 10.88 (C-3-CH₃); HRMS: m/z(M⁺) calcd. for C₁₇H₁₄O₄: 282.0892, found: 283.1008 (M⁺+H).

2-(4-Methoxybenzoyl)-3,6-dimethyl-4H-furo[3,2-c]pyran-4-one (4c)
Colour: white, m.p. 209°C, yield 98%, I.R. (KBr,cm⁻¹): 1746 (O=C=O), 1629 (C=O); ¹H NMR (400 MHz, CDCl₃) δ : 7.99 (d, 2H, C₂/C₆-H, J= 6.88 Hz), 6.99 (d, 2H, C₃/C₅-H, J=6.88 Hz), 6.43 (d, 1H, C7-H, J=0.8 Hz), 3.90 (s, 3H, C₄-OCH₃), 2.66 (s, 3H, C₃-CH₃), 2.37 (s, 3H, C₆-CH₃), ¹³C NMR (100 MHz, CDCl₃): 182.41 (C=O), 163.50 (C-1a), 162.95 (C-4'), 161.66 (C-6), 159.32 (C-2), 148.30 (C-4), 131.89 (C-2'/C-6'), 130.49 (C-1'), 130.11 (C-3), 113.78 (C-3'/C-5'), 109.96 (C-3a), 95.61 (C-7), 55.53 (C-4'-OCH₃), 20.53 (C-6-CH₃), 10.82 (C-3-CH₃); HRMS: m/z(M⁺) calcd. for C₁₇H₁₄O₅: 298.0841, found: 299.0958 (M⁺+H).

(E)-2-Benzoyl-3-(2,5-dimethoxystyryl)-6-methyl-4H-furo[3,2-c]pyran-4-one (5a)
Colour: light yellow, m.p. 162°C, yield 95%, I.R. (KBr,cm⁻¹): 1741 (O=C=O), 1627 (C=O); ¹H NMR (400 MHz, CDCl₃) δ : 8.47 (d, 1H, -CH=CH- Ar, J=16.3 Hz), 7.91 (t, 2H, C₂/C₆-H, J=7.2, 1.6 Hz), 7.77 (d, 1H, -CH=CH- Ar, J=16.3 Hz), 7.62 (t, 1H, C₄-H, J=7.6 Hz), 7.51 (t, 2H, C₃/C₅-H, J=7.6, 7.6 Hz), 7.19 (dd, 1H, C₄', J=8.0, 1.6 Hz), 7.10 (d, 1H, C₆', J=1.6 Hz), 6.87 (d, 1H, C₃', J=8.4 Hz), 6.45 (s, 1H, C₇-H), 3.92 (s, 6H, C₃'-Ar-OCH₃), 2.41 (s, 3H, C₆'-CH₃); ¹³C NMR (100 MHz, CDCl₃): 184.33 (C=O), 163.76 (C-1a), 163.29 (C-6'), 159.23 (C-5'), 149.99 (C-2'), 149.09 (C-2), 146.85 (C-4), 140.76 (C-3), 138.04 (C-1'), 132.59 (C-4'), 132.10 (-CH=CH- Ar), 130.12 (C-2'/C-6'), 129.39 (C-3'/C-5'), 128.41 (-CH=CH- Ar), 121.49 (C-3a), 114.44 (C-1'), 111.05 (C-3'), 109.41 (C-4'), 107.41 (C-6'), 95.58 (C-7), 55.95 (C-5'-OCH₃), 55.93 (C-2'-OCH₃), 20.47 (C-6-CH₃); HRMS: m/z (M⁺) calcd. for C₂₈H₂₀O₆: 416.1260, found: 417.1258 (M⁺+H).
(E)-3-(2,5-Dimethoxystyryl)-6-methyl-2-(4-methylbenzoyl)-4H-furo[3,2-c]pyran-4-one (5b)

Colour: light yellow, m.p. 140°C, yield 95%, I.R. (KBr, cm⁻¹): 1815 (-O=C=O), 1658 (-C=O); ¹H NMR (400 MHz, CDCl₃) δ : 8.73 (d, 1H, -CH=CHAr, J=16.6 Hz), 7.84 (d, 1H, -CH=CHAr, J=16.5 Hz), 7.83 (d, 2H, C₂/C₆'-H, J=8.2 Hz), 7.31 (d, 2H, C₃/C₅'-H, J=8.0 Hz), 7.12 (d, 1H, C₄'-H, J=1.5 Hz), 6.83 (s, 1H, C₆'-C₃', J=1.6 Hz), 6.44 (d, 1H, C₇-H, J=0.7 Hz), 3.84 (s, 6H, C₂'/C₅' -OCH₃), 2.45 (s, 3H, C₆-CH₃), 2.39 (s, 3H, C₄'-CH₃); ¹³C NMR (100 MHz, CDCl₃): 183.95 (-C=O), 163.53 (C-1a), 163.09 (C-6), 159.18 (C-5"), 153.74 (C-2"), 152.54 (C-2), 147.31 (C-4), 143.55 (C-4'), 135.58 (C-3a), 135.29 (C-1'), 131.70 (-CH=CHAr), 129.64 (C-2'/C-6'), 129.11 (C-3'/C-5'), 126.95 (-CH=CH-Ar), 117.08 (C-3a), 115.70 (C-1"), 112.74 (C-3"), 111.99 (C-4"), 107.40 (C-6"), 95.50 (C-7), 56.59 (C-5"-OCH₃), 55.81 (C-2"-OCH₃), 21.72 (C-4'-CH₃), 20.43 (C-6-CH₃); HRMS: m/z (M⁺) calcd. for C₂₆H₂₂O₆: 430.1416, found: 431.1203 (M⁺+H).

(E)-3-(2,5-Dimethoxystyryl)-2-(4-methoxybenzoyl)-6-methyl-4H-furo[3,2-c]pyran-4-one (5c)

Colour: light yellow, m.p. 138°C, yield 95%, I.R. (KBr, cm⁻¹): 1743 (-O-C=O), 1625 (-C=O); ¹H NMR (400 MHz, CDCl₃) δ : 8.70 (d, 1H, -CH=CH-Ar, J=16.7 Hz), 7.96 (dd, 2H, C₂/C₆'-H, J=6.9, 2.0 Hz), 7.82 (d, 1H, -CH=CH-Ar, J=16.5 Hz), 7.13 (t, 1H, C₄'-H, J=1.3, 1.5 Hz), 6.99 (dd, 2H, C₃/C₅'-H, J=6.9, 2.0 Hz), 6.83 (d, 1H, C₅/C₆' -H, J=1.6 Hz), 6.45 (d, 1H, C₇-H, J=0.8 Hz), 3.86 (s, 9H, C₃/C₂/C₅'-OCH₃), 2.40 (s, 3H, C₆-CH₃); ¹³C NMR (100 MHz, CDCl₃): 182.74 (-C=O), 163.41 (C-1a), 163.38 (C-4'), 162.97 (C-6), 159.21 (C-5"), 153.74 (C-2"), 152.50 (C-2), 147.44 (C-4), 135.28 (C-3), 131.99 (-CH=CH-Ar), 131.30 (C-2'/C-6'), 130.51 (C-1'), 126.99 (-CH=CH-Ar), 117.14 (C-3a), 115.67 (C-1"), 113.71 (C-3"), 112.74(C-4"),111.91(C-3'/C-5'), 107.37(C-6"), 95.50(C-7), 56.59(C-5"-OCH₃), 55.82(C-2"-OCH₃),55.53(C-4'OCH₃),20.42(C-6-CH₃); HRMS: m/z (M⁺) calcd. for C₂₆H₂₂O₇: 446.1366, found: 447.1204(M⁺+H).

(E)-2-Benzoyl-3-(2,4-dimethoxystyryl)-6-methyl-4H-furo[3,2-c]pyran-4-one (5d)

Colour: dark yellow, m.p.140°C, yield 95%, I.R. (KBr, cm⁻¹): 1739 (-O-C=O), 1624 (-C=O); ¹H NMR (400 MHz, CDCl₃) δ : 8.73 (d, 1H, -CH=CH-Ar, J=16.6 Hz), 7.90 (m, 2H, C₂/C₆'-H), 7.86 (d, 1H, -CH=CH-Ar, J=16.5Hz), 7.58 (m, 1H, C₄'-H), 7.54 (m, 1H, C₆'-H), 7.51 (m, 2H, C₃/C₅'-H, J=8.9Hz), 6.50 (dd, 1H, C₅'-H, J=2.0, 8.5Hz), 6.45 (d, 1H, C₃'-H, J=2.3Hz),
6.42(d,1H,C7-H,J=0.8Hz), 3.82(s,6H, C2/C4–OCH3), 2.39(s,3H,C6–CH3);
13CNMR(100MHz,CDCl3): 184.22(-C=O),163.58(C-1a), 163.20(C-6),161.66(C-4”),159.31(C-2),159.25(C-4), 146.68(C-2”),138.16(C-3), 136.23(C-1’),133.01(C-4’), 132.53(-CH=CH-Ar),
129.46(C-6”), 128.89(C-2’/C-6”),128.42(C-3’/C-5”),119.29(-CH=CH-Ar), 114.61(C-3a),
107.44(C-1”), 105.14(C-5”), 98.4(C-3”),95.53(C-7), 55.72(C-2”-OCH3),55.43(C-4”-OCH3),
20.43(C-6-CH3); HRMS:m/z(M+) calcd for C25H20O6: 416.1260, found: 417.1308(M̂+H).

(E)-3-(2,4-Dimethoxystyryl)-6-methyl-2-(4-methylbenzoyl)-4H-furo[3,2-c]pyran-4-one(5e)
Colour: dark yellow, m.p.186°C, yield 95%, I.R.(KBr, cm⁻¹): 1741 (-O=C=O), 1627 (-C=O);
1HNMR (400 MHz, CDCl3) δ : 8.71(d, 1H,-CH=CH-Ar, J =16.6 Hz), 7.86 (d, 1H,-CH=CH-Ar, J =16.6 Hz), 7.84 (d, 2H, C2/C6-H, J = 8.2 Hz), 7.56 (d, 1H, C5-H, J = 8.5 Hz), 7.28 (d, 2H, C3/C5-H, J = 7.9 Hz), 6.50 (dd, 1H, C5-H, J=2.0, 8.5 Hz), 6.45 (d, 1H, C3-H, J =2.4 Hz), 6.42 (d, 1H, C7-H, J = 0.8 Hz), 3.89 (s, 6H, C2/C4-CH3), 2.45 (s, 3H, C6-CH3), 2.39 (s, 3H,C4-CH3);
13CNMR (100 MHz, CDCl3) : 183.92 (-C=O), 163.41 (C-1a), 163.05 (C-6), 161.58 (C-4”), 159.27 (C-2), 146.90 (C-4), 143.31 (C-2”), 141.16 (C-4”), 135.90 (C-3), 135.46 (C-1’),132.59 (-CH=CH-Ar), 129.59 (C-6”), 129.05 (C-2’/C-6’), 128.85 (C-3’/C-5’), 119.37 (-CH=CH-Ar), 114.71 (C-3a), 107.32 (C-1”), 105.13 (C-5”), 98.46 (C-3”), 95.52 (C-7), 55.70 (C-2”-OCH3), 55.42 (C-4”-OCH3), 21.71 (C-4’-CH3), 20.41 (C-6-CH3); HRMS: m/z(M̂) calcd. for C26H22O6: 430.1416, found: 431.361(M̂+H).

(E)-3-(2,4-Dimethoxystyryl)-2-(4-methoxybenzoyl)-6-methyl-4H-furo[3,2-c]pyran-4-one(5f)
Colour: dark yellow, m.p.180°C, yield 95%, I.R.(KBr, cm⁻¹): 1741 (-O=C=O),1624 (-C=O);
1HNMR (400 MHz, CDCl3) δ : 8.68 (d, 1H, -CH=CH-Ar, J =16.6 Hz), 7.97 (dd, 2H, C2/C6-H, J = 2.0, 6.8 Hz), 7.84 (d, 1H, -CH=CH-Ar, J = 16.5 Hz), 7.58 (d, 1H, C6-H, J = 8.6 Hz), 6.98 (dd, 2H, C3/C5-H, J = 2.0, 6.9 Hz), 6.51 (dd, 1H, C5-H, J =2.3, 8.4 Hz), 6.45 (d, 1H, C7-H, J = 0.8 Hz), 3.82 (s, 9H, C4/C2/C4-CH3), 2.40 (s, 3H, C6-CH3); 13CNMR (100 MHz, CDCl3) :182.74 (-C=O), 163.30 (C-1a), 163.25 (C-4’), 162.93 (C-6), 161.53 (C-4”), 159.33 (C-2),
159.21 (C-4), 147.02 (C-2”), 135.60 (C-3), 132.21 (-CH=CH-Ar), 131.93 (C-2’/C-6’), 130.67 (C-1”), 128.77 (C-6”), 119.39 (-CH=CH-Ar), 114.75(C-3a),113.66(C-3’/C-5’), 107.39(C-1”),
105.11(C-5”), 98.45(C-3”), 95.53(C-7), 55.71(C-2”-OCH3),55.53(C-4”-OCH3),55.43(C-4’-OCH3),20.42(C-6-CH3); HRMS:m/z(M̂) calcd for C26H22O7: 446.1366, found:
447.1320(M⁺+H).

(E)-2-Benzoyl-3-(3,4-dimethoxystyryl)-6-methyl-4H-furo[3,2-c]pyran-4-one (5g)
Colour: yellow, m.p. 160° C, yield 95%, I.R. (KBr, cm⁻¹): 1739 (-O=C=O), 1624 (-C=O); ¹HNMR (400 MHz, CDCl₃) δ: 8.46(d, 1H, CH=CH-CH=CH-Ar, J=16.4 Hz), 7.91(t, 2H, C₂/C₆-H, J=7.2, 1.4 Hz), 7.76(d, 1H, CH=CH-CH=CH-Ar, J=16.4 Hz), 7.60(t, 1H, C₆-H, J=7.4 Hz), 7.52(t, 2H, C₃/C₅-H, J=1.3, 7.4 Hz), 7.19(dd, 1H, C₅-H, J=1.8, 8.3 Hz), 7.09(d, 1H, C₂-H, J=1.8 Hz), 6.86(d, 1H, C₆-H, J=8.3 Hz), 6.44(d, 1H, C₇-H, J=0.8 Hz), 3.92(s, 6H, C₃/C₄-OCH₃), 2.41(s, 3H, C₆-CH₃); ¹³CNMR (100 MHz, CDCl₃): 184.32 (-C=O), 163.75 (C-1a), 163.28 (C-6), 159.20 (C-3”), 150.01 (C-4”), 149.11 (C-2), 146.86 (C-4), 140.76 (C-3’, 138.05 (C-1’), 132.57 (CH=CH-CH=CH-Ar), 132.09 (C-4’), 130.14 (C-1”), 129.38 (C-2’/C-6’), 128.40 (C-3’/C-5’), 121.48 (CH=CH-CH=CH-Ar), 114.44 (C-3a), 111.08 (C-6”), 109.46 (C-5”), 107.40 (C-2”), 95.56 (C-7), 55.94 (C-3”/C-4”-OCH₃), 20.45 (C-3-CH₃); HRMS: m/z (M⁺) calcd for C₂₅H₂₀O₆: 416.1260, found: 417.1265 (M⁺+H).

(E)-3-(3,4-Dimethoxystyryl)-6-methyl-2-(4-methylbenzoyl)-4H-furo[3,2-c]pyran-4-one (5h)
Colour: yellow, m.p. 134° C, yield 96%, I.R. (KBr, cm⁻¹): 1741 (-O-C=O), 1627 (-C=O); ¹HNMR (400 MHz, CDCl₃) δ: 8.46 (d, 1H, CH=CH-CH=CH-Ar, J=16.4 Hz), 7.85 (d, 2H, C₂/C₆-H, J=8.2 Hz), 7.79 (d, 1H, C₅-H, J=16.4 Hz), 7.33 (d, 2H, C₃/C₅-H, J=8.0 Hz), 7.23 (dd, 1H, C₆-H, J=2.0, 8.4 Hz), 7.12 (d, 1H, C₂-H, J=2.0 Hz), 6.88 (d, 1H, C₇-H, J=8.4 Hz), 6.45 (d, 1H, C₆-H, J=0.8 Hz), 3.94 (s, 6H, C₃/C₄-OCH₃), 2.46 (s, 3H, C₆-CH₃), 2.41 (s, 3H, C₄-CH₃); ¹³CNMR (100 MHz, CDCl₃): 184.03 (-C=O), 163.61 (C-1a), 163.14 (C-6), 159.28 (C-3”), 149.93 (C-4”), 149.08 (C-2), 147.08 (C-4), 143.54 (C-4’), 140.46 (C-3), 135.34 (C-1’), 131.71 (-CH=CH-CH=CH-Ar), 130.20 (C-1”), 129.61 (C-2’/C-6’), 129.12 (C-3’/C-5’), 121.44 (-CH=CH-CH=CH-Ar), 114.55 (C-3a), 111.05 (C-6”), 109.40 (C-5”), 107.39 (C-2”), 95.58 (C-7), 55.94 (C-3”/C-4”-OCH₃), 21.74 (C-4’-CH₃), 20.46 (C-6-CH₃); HRMS: m/z (M⁺) calcd for C₂₆H₂₂O₆: 430.1416, found: 431.1454 (M⁺+H).

(E)-3-(3,4-dimethoxystyryl)-2-(4-methoxybenzoyl)-6-methyl-4H-furo[3,2-c]pyran-4-one (5i)
Colour: yellow, m.p. 139° C, yield 96%, I.R. (KBr, cm⁻¹): 1739 (-O-C=O), 1629 (-C=O); ¹HNMR (400 MHz, CDCl₃) δ: 8.43 (d, 1H, CH=CH-CH=CH-Ar, J=16.4 Hz), 7.98 (d, 2H, C₂/C₆-H, J=
8 Hz), 7.76 (d, 1H, -CH=CH-Ar, J = 16.4 Hz), 7.21 (d, 1H, C\textsubscript{2}-H, J = 8.1 Hz), 7.12 (s, 1H, C\textsubscript{5}-H), 7.01 (d, 2H, C\textsubscript{3}/C\textsubscript{5}-H, J = 8 Hz), 6.88 (dd, 1H, C\textsubscript{6}-H, J = 3.6, 8.3 Hz), 6.46 (d, 1H, C\textsubscript{7}-H, J = 2.8 Hz), 3.91 (s, 9H, C\textsubscript{2}/C\textsubscript{4}-OCH\textsubscript{3}, C\textsubscript{4}-OCH\textsubscript{3}), 2.41 (s, 3H, C\textsubscript{6}-CH\textsubscript{3}); \textsuperscript{13}CNMR (100 MHz, CDCl\textsubscript{3}): 182.82 (-C=O), 163.49 (C-1a), 163.37 (C-4'), 163.02 (C-6), 159.30 (C-3"), 149.87 (C-4"), 149.07 (C-2), 147.21 (C-4), 140.16 (C-3), 131.94 (-CH=CH-Ar), 131.33 (C-2'/C-6'), 130.57 (C-1'), 130.24 (C-1"), 121.38 (-CH=CH-Ar), 114.61 (C-3'/C-5'), 113.72 (C-3a), 111.05 (C-6"), 109.37 (C-5''), 107.35 (C-2''), 95.57 (C-7), 55.95 (C-3''/C-4''-OCH\textsubscript{3}), 55.54 (C-4''-OCH\textsubscript{3}), 20.45 (C-6-CH\textsubscript{3}); HRMS: m/z(M+) calcd. for C\textsubscript{26}H\textsubscript{22}O\textsubscript{7}: 446.1366, found: 447.1381 (M\textsuperscript{+}+H).

\textit{(E)-2-Benzoyl-6-methyl-3-(3,4,5-trimethoxystyryl)-4H-furo[3,2-c]pyran-4-one (5j)}
Colour: light yellow, m.p. 167° C, yield 95%, I.R. (KBr, cm\textsuperscript{-1}): 1743 (-O-C=O), 1625 (-C=O); \textsuperscript{1}HNMR (400 MHz, CDCl\textsubscript{3}) δ: 8.44 (d, 1H, -CH=CH-Ar, J = 16.3 Hz), 7.92 (dd, 2H, C\textsubscript{2}/C\textsubscript{6}-H, J = 1.4, 8.2 Hz), 7.76 (d, 1H, -CH=CH-Ar, J = 16.3 Hz), 7.62 (t, 1H, C\textsubscript{4}-H), 7.53 (t, 2H, C\textsubscript{3}/C\textsubscript{5}-H, J = 7.6 Hz), 6.80 (s, 2H, C\textsubscript{2}/C\textsubscript{6}-H), 6.46 (d, 1H, C\textsubscript{7}-H, J = 0.8 Hz), 3.93 (s, 9H, C\textsubscript{2}/C\textsubscript{4}-OCH\textsubscript{3}), 2.43 (s, 3H, C\textsubscript{6}-CH\textsubscript{3}); \textsuperscript{13}CNMR (100 MHz, CDCl\textsubscript{3}): 184.41 (-C=O), 163.85 (C-1a), 163.35 (C-6), 159.23 (C-3''/C-5''), 153.36 (C-2), 147.08 (C-4), 140.70 (C-3), 138.96 (C-4''), 138.96 (C-1'), 137.96 (C-1''), 132.70 (-CH=CH-Ar), 131.62 (C-4'), 129.41 (C-2'/C-6'), 128.45 (C-3'/C-5'), 115.77 (-CH=CH-Ar), 107.39 (C-3a), 104.49 (C-2''/C-6''), 95.59 (C-7), 60.99 (C-4''-OCH\textsubscript{3}), 56.19 (C-3''/C-5''-OCH\textsubscript{3}), 20.49 (C-6-CH\textsubscript{3}); HRMS: m/z(M+) calcd. for C\textsubscript{26}H\textsubscript{22}O\textsubscript{7}: 446.1366, found: 447.1381 (M\textsuperscript{+}+H).

\textit{(E)-6-Methyl-2-(4-methylbenzoyl)-3-(3,4,5-trimethoxystyryl)-4H-furo[3,2-c]pyran-4-one (5k)}
Colour: light yellow, m.p.140° C, yield 95%, I.R. (KBr, cm\textsuperscript{-1}): 1737 (-O-C=O), 1634 (-C=O); \textsuperscript{1}HNMR (400 MHz, CDCl\textsubscript{3}) δ: 8.42 (d, 1H, -CH=CH-Ar, J = 16.3 Hz), 7.84 (d, 2H, C\textsubscript{2}/C\textsubscript{6}-H, J = 8.1 Hz), 7.77 (d, 1H, -CH=CH-Ar, J = 16.3 Hz), 7.32 (d, 2H, C\textsubscript{3}/C\textsubscript{5}-H, J = 8.1 Hz), 6.82 (s, 2H, C\textsubscript{2}/C\textsubscript{6}-H), 6.45 (d, 1H, C\textsubscript{7}-H, J = 0.8 Hz), 3.83 (s, 12H, C\textsubscript{3}/C\textsubscript{4}/C\textsubscript{5}-OCH\textsubscript{3}), 2.45 (s, 3H, C\textsubscript{6}-CH\textsubscript{3}), 2.41 (s, 3H, C\textsubscript{4}-CH\textsubscript{3}); \textsuperscript{13}CNMR (100 MHz, CDCl\textsubscript{3}): 184.06 (-C=O), 163.66 (C-1a), 159.25 (C-6), 153.35 (C-3''/C-5''), 152.42 (C-2), 147.30 (C-4), 143.66 (C-4''), 140.39 (C-3), 138.94 (C-4''), 135.27 (C-1''), 132.77 (-CH=CH-Ar), 131.19 (C-1'), 129.63 (C-2'/C-6'), 128.99 (C-3'/C-5'), 115.87 (-CH=CH-Ar), 107.36 (C-3a), 104.51 (C-2''/C-6''), 95.57 (C-7), 60.97 (C-4''-OCH\textsubscript{3}), 56.16 (C-3''/C-5''-OCH\textsubscript{3}),
21.73(C-4′-CH₃), 20.45(C-6-CH₃); HRMS: m/z (M⁺) calcd. for C₂₇H₂₄O₇: 460.1522, found: 461.1659(M⁺+H).

(E)-2-(4-Methoxybenzoyl)-6-methyl-3-(3,4,5-trimethoxystyril)-4H-furo[3,2-c]pyran-4-one (5l)
Colour: light yellow, m.p.143°C, yield 95%, I.R. (KBr, cm⁻¹): 1734 (-O-C=O), 1616 (-C=O);
¹HNMR (400 MHz, CDCl₃) δ: 8.40 (d, 1H, -CH=CH-, J=16.3Hz), 7.96 (d, 2H, 7,7, J=8.9 Hz), 7.73 (d, 1H, -CH=CH-, J=16.3Hz), 7.00 (d, 2H, C₃/C₅-H, J=8.9 Hz), 6.80 (s, 2H, C₂/C₆-H), 6.47 (d, 1H, C₇-H, J=0.8Hz), 3.84 (s, 12H, C₃/C₄/C₅/OCH₃, C₄-OCH₃), 2.41 (s, 3H, C₆-CH₃); ¹³CNMR (100 MHz, CDCl₃): 182.88 (-C=O), 163.56 (C-1a), 163.45 (C-4′), 163.08 (C-6), 159.30 (C-3′/C-5′), 153.34 (C-2), 147.45 (C-4), 140.08 (C-3), 138.84 (C-4′), 132.82 (C-1′), 131.97 (-CH=CH-), 130.81 (C-2′/C-6′), 130.50 (C-1′), 115.95 (-CH=CH-), 113.75 (C-3a), 107.33 (C-3′/C-5′), 104.42 (C-2′/C-6′), 95.58 (C-7), 60.97 (C-4′-OCH₃), 56.16 (C-3′/C-5′-OCH₃), 55.54 (C-4′-OCH₃), 20.46 (C-6-CH₃); HRMS: m/z (M⁺) calcd. for C₂₇H₂₄O₇: 476.1471, found: 477.1550(M⁺+H).

2-Benzylox-3-methyl-4H-furo[3,2-c]chromen-4-one (8a)
Colour: white, m.p. 141°C, yield 92%, I.R. (KBr, cm⁻¹): 1753 (-O-C=O), 1672 (-C=O); ¹HNMR: (400 MHz, CDCl₃) δ: 8.03 (d, 2H, C₂/C₆-H, J=7.08 Hz), 7.91 (dd, 1H, C₃-H, J=7.8, 7.8 Hz), 7.60-7.65 (m, 2H, C₄-H and C₇-H), 7.56 (t, 2H, C₃/C₅-H), 7.47 (d, 1H, C₆-H, J=8.3 Hz), 7.38 (t, 1H, C₈-H, J=6.8, 8.3 Hz), 2.76 (s, 3H, C₃-CH₃), ¹³C NMR (100 MHz, CDCl₃) δ: 183.96 (-C=O), 157.84 (C-9b), 157.75 (C-4), 153.75 (C-5a), 149.07 (C-2), 137.33 (C-1′), 132.97 (C-4′), 132.31 (C-7), 132.01 (C-3), 129.47 (C-2′/C-6′), 128.54 (C-3′/C-5′), 124.83 (C-8), 121.75 (C-9), 117.59 (C-6), 112.20 (C-3a), 111.95 (C-9a), 10.82 (C-3-CH₃); HRMS: (m/z) M⁺ calcd. for C₁₉H₁₂O₄: 304.0736, found: 305.0798 (M⁺+H).

3-Methyl-2-(4-methylbenzoyl)-4H-furo[3,2-c]chromen-4-one (8b)
Colour: light brown, m.p. 108°C, yield: 90%, IR (KBr, cm⁻¹): 1726 (-O-C=O), 1656 (-C=O); ¹HNMR: (400 MHz, CDCl₃) δ: 7.95 (d, 2H, C₂/C₆-H, J=8.4 Hz), 7.91 (dd, 1H, C₃-H, J=7.8 Hz), 7.57-7.62 (m, 1H, C₇-H), 7.47 (d, 1H, C₆-H, J=7.6 Hz), 7.35-7.39 (m, 3H, C₈-H, C₉/C₉-H), 2.74 (s, 3H, C₃-CH₃), 2.38 (s, 3H, C₄-CH₃); ¹³C NMR (100 MHz, CDCl₃) δ: 183.64
(-C=O), 163.06 (C-9b), 161.77 (C-5a), 159.29 (C-2), 148.15 (C-4), 143.67 (C-4'), 134.77 (C-1'), 132.30 (C-7), 130.86 (C-3), 129.54 (C-2'/C-6'), 129.14 (C-3'/C-5'), 124.8(C-8), 121.7 (C-9), 117.6 (C-6), 112.2 (C-3a), 111.9 (C-9a), 21.71 (C-4'-CH₃), 10.85 (C-3-CH₃);
HRMS: (m/z) M⁺ calcd. for C₂₀H₁₄O₄: 318.892, found: 319.0955 (M⁺+H).

2-(4-Methoxybenzoyl)-3-methyl-4H-furo[3,2-c]chromen-4-one (8c)
Colour: white, m.p. 110° C, yield 90%, IR ( KBr, cm⁻¹) : 1746 (-O-C=O), 1632 (-C=O);
¹H NMR (400 MHz, CDCl₃) δ: 8.08 (d, 1H, C₆-H, J = 8.7 Hz), 7.94 (t, 1H, C₇-H, J = 8.9, 9.3 Hz), 7.75 (d, 1H, C₆-H, J = 8.4 Hz), 7.59 (t, 1H, C₈-H, J = 6.9, 7.2 Hz), 7.36 (m, 2H, C₂'/C₆'-H), 6.99-7.05 (m, 2H, C₃/₅-H), 3.88-3.93 (s, 3H, C₄-CH₃), 2.75 (s, 3H, C₃-CH₃); ¹³C NMR (100 MHz, CDCl₃) : 182.41 (-C=O), 163.46 (C-9b), 162.93 (C-4'), 161.62 (C-5a), 159.34 (C-2), 148.24 (C-4), 132.38 (C-7), 131.88 (C-2'/C-6'), 130.48 (C-1'), 130.04 (C-3), 124.8 (C-8), 121.7 (C-9), 117.6 (C-6), 113.75 (C-3'/C-5'), 112.2 (C-3a), 111.9 (C-9a), 55.52 (C-4'-CH₃), 10.85 (C-3-CH₃); HRMS: m/z M⁺ calcd. for C₂₀H₁₄O₅: 334.0841, found: 335.0901 (M⁺+H).

(E)-2-Benzoyl-3-(2,5-dimethoxystyrlyl)-4H-furo[3,2-c]chromen-4-one (9a)
Colour: yellow, m.p. 140° C, yield 97%, I.R. ( KBr, cm⁻¹) : 1753 (-O-C=O), 1600 (-C=O);
¹H NMR: (400 MHz, CDCl₃) δ: 8.75 (d,1H, -CH=CH-Ar, J = 16.0 Hz), 8.00 (d, 2H, C₂/C₆-H, J = 8.0 Hz), 7.93 (d, 1H, -CH=CH-Ar, J = 16.0 Hz), 7.90 (dd, 1H, C₅-H, J = 1.2, 8.4 Hz), 7.59-7.65 (m, 2H, C₈-H, C₄-H), 7.55 (t, 2H, C₃/₅-H, J = 8.9 Hz), 7.48 (d, 1H, C₆-H, J = 7.6 Hz), 7.37 (m, 1H, C₇-H), 7.17 (s, 1H, C₄-Ar), 6.85 (s, 2H, C₃/₅-H), 3.81, 3.88 (s, 6H, C₂-OCH₃ and C₅-OCH₃); ¹³C NMR (100 MHz, CDCl₃) δ: 184.17(-C=O), 158.93 (C-9b), 157.58 (C-5'), 153.84 (C-2''), 152.67 (C-4), 148.16 (C-5a), 137.94 (C-1'), 136.28 (-CH=CH-Ar), 132.79 (C-4'), 132.70 (C-7), 132.54 (C-3), 129.56 (C-2'/C-6'), 128.49 (C-3'/C-5'), 126.88 (-CH=CH-Ar), 124.75 (C-8), 121.94 (C-9), 117.32 (C-6), 116.70 (C-3a)115.97 (C-1''), 112.84 (C-6''), 112.17 (C-3''), 111.89 (C-4''), 109.66 (C-9a), 56.64, 55.89 (C-2'',C-5''-OCH₃); HRMS: (m/z) M⁺ calcd. for C₂₈H₂₈O₆: 452.1260, found: 453.1354 (M⁺+H).

(E)-3-(2,5-Dimethoxystyrlyl)-2-(4-methylbenzoyl)-4H-furo[3,2-c]chromen-4-one (9b)
Colour: yellow, m.p. 146° C, yield 95%, I.R. ( KBr, cm⁻¹) : 1744 (-O-C=O), 1620 (-C=O);
¹H NMR: (400 MHz, CDCl₃) δ: 8.74(d,1H, -CH=CH-Ar, J = 16.6 Hz), 7.89-7.93(m, 4H, -
\( \text{CH}=\text{CH}-\text{Ar}, \text{C}_9\text{H}, \text{C}_2/\text{C}_6\text{-H}, 7.59-7.63 \text{ (m, 1H, C}_7\text{-H)}, 7.48 \text{ (d, 1H, C}_6\text{-H, J = 8.0 Hz), 7.34-7.39} \text{ (m, 1H, C}_8\text{-H, C}_3/\text{C}_5\text{-H), 7.17 (s, 1H, C}_4\text{-H), 6.85 (s, 2H, C}_2/\text{C}_6\text{-H), 3.81, 3.88 (s, 6H, C}_2/\text{C}_5\text{-OCH}_3), 2.47 (s, 1H, C}_4\text{- CH}_3\); \( ^{13}\text{C NMR (100 MHz, CDCl}_3 \text{) \delta: 183.95 (C=O), 163.53 (C-9b), 163.09 (C-5a), 159.18 (C-5”), 153.74 (C-2”), 152.54 (C-2), 147.31 (C-4), 143.55 (C-4’), 135.58 (C-3), 135.29 (C-1”), 131.70 (C=CH=CH-Ar), 126.64 (C-2’/C-5’), 126.95 (C=CH=CH-Ar), 124.45 (C-8), 121.13 (C-9), 117.46 (C-6), 117.08 (C-3a), 115.70 (C-1”), 112.74 (C-6”), 111.99 (C-3”), 107.40 (C-4”), 95.50 (C-7), 56.59 (C-5”-OCH)_3, 55.81 (C-2”-OCH)_3, 20.43 (C-4’-CH)_3; HRMS: (m/z) M^+ calcd. for C\(_{29}\)H\(_{22}\)O\(_6\): 466.1416, found: 467.1518 (M^+H). \)

\((E)-3-(2,5\text{-Dimethoxy styryl})-2-(4\text{-methoxybenzoyl})-4\text{-H-furo[3,2-c]chromen-4-one (9c)}\)

Colour: yellow, m.p. 180° C, yield 95%, I.R. (KBr, cm\(^{-1}\)) : 1754 (\(-\text{O-C}=\text{O}\)), 1627 (\(-\text{C}=\text{O}\)); \(^1\text{HNMR: (400 MHz, CDCl}_3 \text{) \delta: 8.71 (d, 1H, -CH=CH-Ar, J = 16.6 Hz), 8.05 (d, 2H, C}_2/\text{C}_6\text{-H, J = 8.9 Hz), 7.93 (dd, 1H, C}_9\text{-H, J = 1.2, 8.4 Hz), 7.89 (d, 1H, -CH=CH-Ar, J = 16.5 Hz), 7.60-7.64 (m, 1H, C}_7\text{-H), 7.48 (d, 1H, C}_6\text{-H, J = 7.6 Hz), 7.36-7.41 (m, 1H, C}_8\text{-H), 7.17 (s, 1H, C}_4\text{-H), 7.03 (d, 2H, C}_3/\text{C}_5\text{-H, J = 8.9 Hz), 6.84 (s, 2H, C}_2/\text{C}_6\text{-H), 3.81, 3.88, 3.92 (s, 9H, C}_2/\text{C}_5\text{-CH}_3, C}_4\text{-OCH}_3); ^{13}\text{C NMR (100 MHz, CDCl}_3 \text{) \delta: 182.69 (C=O), 163.57 (C-9b), 153.79 (C-4’), 153.74 (C-5”), 152.55 (C-2”), 135.60 (C-5a), 132.39 (C-2), 132.10 (C-2’/C-6’), 130.48 (C-7), 126.96 (C-1”), 124.72 (C-3), 121.85 (C-8), 117.30 (C-9), 116.82 (C-6), 115.77 (C-1”), 113.84 (C-3’,C-5’), 112.76 (C-3”), 112.05 (C-4”), 111.97 (C-6”) 56.61, 55.85, 55.56 (C-2”, C-5”,C-4’-OCH)_3; HRMS: (m/z) M^+ calcd. for C\(_{29}\)H\(_{22}\)O\(_6\): 482.1366, found: 483.1472 (M^+H). \)

\((E)-2\text{-Benzoyl-3-(3,4,5-trimethoxy styryl})-4\text{-H-furo[3,2-c]chromen-4-one (9d)}\)

Colour: yellow, m.p. 191° C, yield 94%, I.R. (KBr, cm\(^{-1}\)) : 1734 (\(-\text{O-C}=\text{O}\)), 1627 (\(-\text{C}=\text{O}\)); \(^1\text{HNMR: (400 MHz, CDCl}_3 \text{) \delta: 8.47 (d, 1H, -CH=CH-Ar, J = 16.3 Hz), 8.01 (d, 2H, C}_2/\text{C}_6\text{-H, J = 7.6 Hz), 7.91 (dd, 1H, C}_9\text{-H, J = 7.8, 7.6 Hz), 7.83 (1H, d, CH=CH-Ar, J = 16.3 Hz), 7.83 (d, 1H, CH=CH-Ar, J = 16.3 Hz),7.62-7.67 (m, 2H, C}_8\text{-H, C}_4\text{-H), 7.55-7.59 (m, 2H, C}_3/\text{C}_5\text{-H), 7.50 (d, 1H, C}_6\text{-H, J = 8.0 Hz), 7.40 (t, 1H, C}_7\text{-H, J = 5.1, 7.6 Hz), 6.84 (s, 2H, C}_2/\text{C}_6\text{-H)3.77-3.92 (s, 9H, C}_3/\text{C}_4/\text{C}_5\text{-OCH}_3); ^{13}\text{CNMR (100 MHz, CDCl}_3 \text{) \delta: 184.41 (C=O), 163.85 (C-9b), 163.35 (C-5a), 159.23 (C-3’/C-5”), 153.36 (C-2), 147.08 (C-4), 140.70 (C-3), 138.96 (C-4”), 138.96 (C-1’), 137.96 (C-1”), 132.79 (-CH=CH-Ar), 132.70 (C-9a), 131.62 (C}
-4'), 129.41 (C-2'/C-6'), 128.45 (C-3'/C-5'), 125.52 (C-8), 120.05 (C-9), 117.34 (C-6) 115.77 (-CH=CH-Ar), 107.39 (C-3a), 104.49 (C-2''/C-6''), 95.59 (C-7), 60.99 (C-4''-OCH₃), 56.19 (C-3''/C-5''-OCH₃); HRMS: (m/z) M⁺ calcd. for C₂₉H₂₂O₇: 482.1366, found: 483.1494 (M⁺+H).

(E)-3-(3,4,5-Trimethoxystyryl)-2-(4-methylbenzoyl)-4H-furo[3,2-c]chromen-4-one (9e)

Colour: yellow, m.p. 181⁰C, yield 94%, I.R. (KBr, cm⁻¹): 1724 (-O-C=O), 1629 (-C=O); ¹HNMR: (400 MHz, CDCl₃) δ: 8.45 (d, 1H, -CH=CH-Ar, J = 16.4 Hz), 7.91-7.94 (m, 3H, -CH=CH-Ar, C₇-H, C₂/C₆-H), 7.83 (d, 1H, -CH=CH-Ar, J = 16.3 Hz), 7.63 (t, 1H, C₇-H, J = 8.4 Hz), 7.50 (d, 1H, C₆-H, J = 8.2 Hz), 7.35-7.41 (m, 3H, C₈-H, C₃/C₅-H), 6.84 (s, 2H, C₂-H and C₆-H), 3.88, 3.92 (s, 9H, C₃=OCH₃, C₄=OCH₃ and C₅=OCH₃), 2.48 (s, 1H, C₄-CH₃); ¹³CNMR (100 MHz, CDCl₃): 183.55 (-C=O), 157.72 (C-9b), 153.77 (C-5'', C-3''), 153.41 (C-4''), 148.36 (C-5a), 143.87 (C-4''), 140.67 (C-1''), 135.64 (C-1''), 131.77 (-CH=CH-Ar), 129.75 (C-2'/C-6''), 129.24 (C-3'/C-5'), 128.99 (C-3), 124.82 (C-8), 121.92 (C-9), 118.92 (-CH=CH-Ar), 117.32 (C-6), 115.57 (C-3a), 111.89 (C-9a), 104.46 (C-2'', C-6'') 60.96 (C-4''-OCH₃), 56.21 (C-3''/C-5''-OCH₃), 21.74 (C-4'-CH₃); HRMS: (m/z) M⁺ calcd. for C₃₀H₂₄O₇: 496.1522, found: 497.1768 (M⁺+H).

(E)-3-(3,4,5-Trimethoxystyryl)-2-(4-methoxybenzoyl)-4H-furo[3,2-c]chromen-4-one (9f)

Colour: yellow, m.p. 183⁰C, yield 94%, I.R. (KBr, cm⁻¹): 1746 (-O-C=O), 1637 (-C=O); ¹HNMR: (400 MHz, CDCl₃) δ: 8.45 (d, 1H, -CH=CH-Ar, J = 16.4 Hz), 8.07 (d, 2H, C₂/C₆-H, J = 8.8 Hz), 7.96 (d, 1H, C₇-H, J = 7.7 Hz), 7.82 (d, 1H, -CH=CH-Ar, J = 16.4 Hz), 7.66 (t, 1H, C₇-H, J = 7.1 Hz), 7.53 (d, 1H, C₆-H, J = 8.4 Hz), 7.42 (t, 1H, C₈-H, J = 7.6 Hz), 7.07 (d, 2H, C₃/C₅-H, J = 8.8 Hz), 6.86 (s, 2H, C₂' and C₆'-H), 3.95, 3.94, 3.92, 3.90 (s, 12H, C₄'=OCH₃, C₃', C₄'=OCH₃ and C₅'=OCH₃); ¹³CNMR (100 MHz, CDCl₃): 183.52 (-C=O), 156.51 (C-3'', C-5''), 153.19 (C-4''), 141.43 (C-1''), 139.66 (C-4''), 133.25 (-CH=CH-Ar), 131.90 (C-1''), 127.57 (C-2', C-6''), 126.23 (C-3', C-5''), 123.07 (-CH=CH-Ar), 121.23 (C-9), 116.23 (C-6), 105.51 (C-2'', C-6''), 60.79 (C-4''-OCH₃), 56.11 (C-3'', C-4', C-5''-OCH₃); HRMS: (m/z) M⁺ calcd. for C₃₀H₂₄O₈: 512.1471, found: 513.1692 (M⁺+H).
Pharmacological/biological assays

Anticancer activity culture

To relate the degree of propagation of a tumor cell line in the absence and presence of the test substances furo[3,2-c]pyran-4-ones (4, 5) and furo[3,2-c]chromen-4-ones (8, 9), generally later a listed time the sulphorhodamine B (SRB) [1] evaluation is carried out. This trusts on the uptake other negatively charged pink aminoxanthine dye, sulphorhodamine B (SRB) using amino acids (basic) in the cells. Larger the number of cells, the more amount of dye is taken up then after fixing, the cells are lysed and the released dye will give a more intense colour and better absorbance. Cells were cultured in a 96 well plate. Inoculation densities per well varies from cell line to cell line under investigation. 100 µL of cell suspension was plated. The cells were then treated with 50 µM concentration of test compound complete growth medium (RPMI-1640) for 48 hours. After 48 hours of incubation at 37°C, cells were washed for 1h with ice cold TCA at 4°C. After fixing the cells in fixative, the plates were rinsed with water for three times and it was further allowed to air dry. 100µL of 0.4% SRB dye was added for half an hour at room temperature after drying. 1% v/v acetic acid is then used for washing plates 3 times to remove any unbound SRB. The plates are then kept for drying at room temperature, after drying the bound dye was solubilized by adding 100 µL of 10mM TRIS buffer having pH-10.4 to each well. The plates were shaking for 5 minutes to solubilize the dye. Finally, OD was taken at 540 nm in a microplate reader. IC50 was determined by plotting OD against concentration.

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\text{The } \% \text{ of cell viability} = \frac{\text{Absorbance of treated cells-Absorbance of blank}}{\text{Absorbance of control cells-Absorbance of blank}} \times 100
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\% \text{ Growth inhibition} = 100- \% \text{ cell viability}
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4.2.2 Antimicrobial activity cultures

The antimicrobial screening of the synthesized furo[3,2-c]pyran-4-ones (4,5) and furo[3,2-c]chromen-4-ones (8, 9) were carried out against three bacterial strains i.e. *Bacillus sublitis* (MTCC-441), *Staphylococcus aureus* (MTCC 3160) and *Escherichia coli* (MTCC-443) and two fungal strains i.e. *Candida albicans* (MTCC-227) and *Aspergillus niger* (MTCC-281) employing tube dilution method [2]. Dilutions of standard and test compounds were done in double strength nutrient broth I.P. and Sabouraud dextrose broth I.P. for bacteria and fungi. The testing compounds were incubated for 24 h at 37°C±1°C for all bacteria and 25°C for seven days for fungi *A. niger* or for 48 h at 37°C±1°C for fungi *C. albicans*. Results of activities were noted in terms of MIC. Graphical representation of antibacterial study is represented in Fig. 2.
Fig. 2. Show the graphical representation of antibacterial study of synthesized compounds (4, 5, 8 and 9).
Graphical representation of antifungal study is represented in Fig. 3.

Fig. 3 The graphical representation of antifungal study of synthesized compounds (4, 5, 8, 9)
$^1$H, $^{13}$C NMR, 2D and HRMS spectra of synthesized compounds

Figure S1. $^1$H NMR of compound 4a

Figure S2. $^1$H NMR of compound 4b
Figure S3. $^1$H NMR of compound 4c

Figure S4. $^1$H NMR of compound 5a
Figure S5. $^1$H NMR of compound 5b

Figure S6. $^1$H NMR of compound 5c
Figure S7. $^1$H NMR of compound 5d

Figure S8. $^1$H NMR of compound 5e
Figure S9. $^1$H NMR of compound 5f

Figure S10. $^1$H NMR of compound 5g
Figure S11. $^1$H NMR of compound 5h

Figure S12. $^1$H NMR of compound 5i
Figure S13. $^1$H NMR of compound 5j

Figure S14. $^1$H NMR of compound 5k
Figure S15. $^1$H NMR of compound 5l

Figure S16. $^1$H NMR of compound 8a
Figure S17. $^1$H NMR of compound 8b

Figure S18. $^1$H NMR of compound 8c
Figure S19. $^1$H NMR of compound 9a

Figure S20. $^1$H NMR of compound 9b
Figure S21. $^1$H NMR of compound 9c

Figure S22. $^1$H NMR of compound 9d
Figure S23. $^1$H NMR of compound 9e

Figure S24. $^1$H NMR of compound 9f
Figure S 25. $\text{^{13}C NMR}$ of compound 4a

Figure S 26. $\text{^{15}C NMR}$ of compound 4b
Figure S 27. $^{13}$C NMR of compound 4c

Figure S 28. $^{13}$C NMR of compound 5a
Figure S 29. $^{13}$C NMR of compound 5b

Figure S 30. $^{13}$C NMR of compound 5c
Figure S31. $^{13}$C NMR of compound 5d

Figure S32. $^{13}$C NMR of compound 5e
Figure S 33. \(^{13}\text{C}\) NMR of compound 5f

Figure S 34. \(^{13}\text{C}\) NMR of compound 5g
Figure S 35. $^{13}$C NMR of compound 5h

Figure S 36. $^{13}$C NMR of compound 5i
Figure S37. $^{13}$C NMR of compound 5j

Figure S38. $^{13}$C NMR of compound 5k
Figure S 39. $^{13}$C NMR of compound 5l

Figure S 40. $^{13}$C NMR of compound 8a
Figure S 41. $^{13}$C NMR of compound 9a

Figure S 42. $^{13}$C NMR of compound 9b
Figure S 43. $^{13}$C NMR of compound 9c

Figure S 44. $^{13}$C NMR of compound 9d
Figure S 45. $^{13}$C NMR of compound 9c

Figure S 46. $^{13}$C NMR of compound 9f
Figure S 47. DEPT of compound 4c

Figure S 48. 2D NMR (COSY) of compound 4c
Figure S 49.2D NMR (MLEPSHW) of compound 4c

Figure S 50.2D NMR (HSQC) of compound 4c
Figure S 51. HRMS of compound 8a

Figure S 52. HRMS of compound 8b
Figure S 53. HRMS of compound 8c

Figure S 54. HRMS of compound 5a
Figure S 55. HRMS of compound 5b

Figure S 56. HRMS of compound 5c
Figure S 57. HRMS of compound 5d

Figure S 58. HRMS of compound 5e
Figure S 59. HRMS of compound 5f

Figure S 60. HRMS of compound 5g
Figure S 61. HRMS of compound 5h

Figure S 62. HRMS of compound 5i
Figure S 63. HRMS of compound 9a

Figure S 64. HRMS of compound 9b
Figure S 65. HRMS of compound 9c

Figure S 66. HRMS of compound 9d
Figure S 67. HRMS of compound 9e

Figure S 68. HRMS of compound 9f
References
