



ORIGINAL ARTICLE

Succinimide-*N*-sulfonic acid: An efficient and recyclable catalyst for the one-pot synthesis of tetrahydrobenzo[*c*]acridine-8(7*H*)-one derivatives



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Abstract Synthesis of substituted 10,10-dimethyl-7-phenyl-9,10,11,12-tetrahydrobenzo[*c*]acridin-8(7*H*)-one derivatives proceeded by the one-pot reaction of aromatic aldehydes, 5,5-dimethylcyclohexane-1,3-dione (dimedone) and 1-naphthylamine, in the presence of Succinimide-*N*-sulfonic acid (SuSA) has been reported. Simplicity of operation, high yields, easy work-up and a wide range of substrate applicabilities are the key advantages of this methodology. Furthermore, the catalyst can be recovered conveniently and reused efficiently.

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1. Introduction

Multicomponent reactions (MCRs), are powerful synthetic tools which have changed the landscape of organic and medicinal chemistry because of environmental concerns by reducing the number of synthetic steps, energy consumption and waste production. Moreover, MCRs offer the advantage of simplicity and synthetic efficiency over conventional chemical reactions. Therefore, search and discovery for new MCRs, along

with full exploitation of the already known MCRs are of considerable interest [26].

Acridine derivatives have attracted considerable attention due to their potential pharmacological activity. Several novel isoquino[4,5-*bc*]acridine derivatives have been designed and synthesized. Their DNA-binding, anti-tumor and DNA photo-damaging properties were investigated [23]. For hundreds of years, leishmaniases have been the cause of death among millions of people throughout the world. Newly synthesized 4,5-di-substituted acridines were assessed for *in vitro* antileishmanial activities as compared to those of their 4-mono-substituted homologs [1]. Six new 2,2,7,7-tetramethyl-9-aryl-2,3,4,5,6,7,9,10-octahydro-1,8-acridinedione derivatives were synthesized and their functional effects on vascular potassium channels and mechanism of induced relaxations on phenylephrine-induced contractile responses in isolated rat mesenteric arteries were investigated [18]. Acridinediones

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containing thiourea and piperazine moieties, and vanilline derived acridinediones were synthesized and studied for antimicrobial activities [8]. A series of novel imidazolyl derivatives of fully and partially hydrogenated 1,8-acridinediones were synthesized and assessed for their cytotoxic activity on four different human cancer cell lines [7]. In addition, acridinediones also exhibit anti-malarial [5] and anti-cancer [2] activities.

An acridinedione modified β -cyclodextrin has been reported recently. The modified compound well resembled the native acridinedione dyes in fluorescent properties. An efficient FRET process was observed with safranin dye as acceptor and the modified compound as the energy donor [9]. Seven difunctional acridinediones DAD were prepared and investigated for their abilities to initiate a ring-opening cationic photopolymerization in combination with an iodonium salt upon UV/visible light or visible light (halogen lamp) exposure [22]. The aza-crown ether acridinedione-functionalized gold nanoparticles (ACEADD-GNPs) have been synthesized and investigated as a fluorescent chemosensor for metal ions [19]. A dual emitting acridinedione fluorophore, 9-(4-(dimethylamino)phenyl)-3,4,6,7,9,10-hexahydroacridine-1,8(2*H*,5*H*)-dione (DMAADR-1), was synthesized and its dual fluorescence behavior was found to be greatly affected by the presence of both transition metal ions and anions [10]. Similarly, the design and synthesis of acridinedione functionalized gold nanoparticles based PET anion sensor are also described [20]. As a consequence, the interest of organic chemists in the synthesis or structure modifications of acridine derivatives remains high.

Given the importance of pharmacological and other properties, there are many methods available for the construction of benzoacridine derivatives, for instance, by the condensation of appropriate aldehyde, naphthylamine and dimedone using the ultrasound-promoted method [24,25], microwave-induced synthesis [13], H₂O catalyzed by TEBA [21] and using L-proline as catalyst [6]. These methods all have their own merits and shortcomings. However, many of these methods suffer from drawbacks such as the use of hazardous organic solvents, long reaction time and low-yields. Therefore, the development of a mild generalized method to overcome these shortcomings still remains an ongoing challenge for the synthesis of highly substituted tetrahydrobenzo[*c*]acridin-8-ones for organic chemists.

In recent years Succinimide-*N*-sulfonic acid (SuSA) has drawn much interest in different organic reactions due to its experimental simplicity. The preparation of Succinimide-*N*-sulfonic acid (SuSA) is reported recently by the reaction of succinimide with chlorosulfonic acid. This reagent is able to efficiently catalyze the chemoselective trimethylsilylation of alcohols and phenols with hexamethyldisilazane (HMDS) [14]. SuSA has shown considerable catalytic efficiency in different transformations such as chemoselective conversion of amines to their corresponding *N*-Boc protected derivatives with (Boc)₂O [15], synthesis of xanthene derivatives *via* three component condensation of aldehydes with 2-naphthol, 1,3-cyclohexanedione and/or a mixture of 2-naphthol and 1,3-cyclohexanediones under solvent-free conditions [16] and also for the acetylation reactions in the absence of a solvent [17].

To our best knowledge, there is no report in the literature on the preparation of tetrahydrobenzo[*c*]acridin-8-one derivatives using SuSA. As part of our efforts to develop new synthetic methods in heterocyclic chemistry [11,12,3,4], herein we report for SuSA catalyzed three-component reaction of aromatic aldehydes, dimedone and 1-naphthylamine for the

synthesis of 9,10,11,12-tetrahydrobenzo[*c*]acridin-8-one derivatives in EtOH at 60 °C.

2. Experimental

2.1. Chemicals and apparatus

Chemicals were purchased from Merck, Fluka and Aldrich Chemical Companies. All yields refer to isolated products unless otherwise stated. ¹H NMR (500 MHz) and ¹³C NMR (125 MHz) spectra were obtained using Bruker DRX-500 Avance at ambient temperature, using TMS as internal standard. FT-IR spectra were obtained as KBr disks on Shimadzu spectrometer. Mass spectra were determined on a Varian – Saturn 2000 GC/MS instrument. Elemental analysis was measured by means of a Perkin Elmer 2400 CHN elemental analyzer flowchart.

2.2. Preparation of Succinimide-*N*-sulfonic acid

Succinimide-*N*-sulfonic acid as a stable reagent is easily prepared as reported previously by the reaction of succinimide with neat chlorosulfonic acid (Scheme 1) [14].

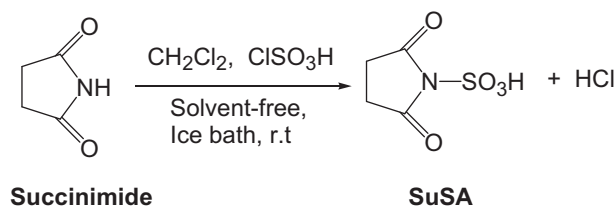
2.3. General procedure for the synthesis of substituted tetrahydrobenzo[*c*]acridin-8(7*H*)-one derivatives (4*a*–*l*)

In a 50 mL round bottom flask aromatic aldehyde (1 mmol), dimedone (1 mmol) and 1-naphthylamine (1 mmol) were stirred in the presence of SuSA (4 mol%) in EtOH (5 mL) at 60 °C for the stipulated time. The progress of the reaction was monitored by TLC. After completion of the reaction, the reaction mixture was diluted with water (5 mL) and extracted with ethyl acetate (3 × 10 mL). The organic layer was dried over anhydrous Na₂SO₄, concentrated, and recrystallized from hot ethanol to afford the pure product.

2.4. Characterization data of synthesized compounds 4*a*–*l*

2.4.1. 10,10-Dimethyl-7-phenyl-9,10,11,12-tetrahydrobenzo[*c*]acridin-8(7*H*)-one (4*a*)

White crystal; IR (KBr, cm⁻¹): 3312, 3077, 2888, 1672, 1566, 1511, 1433, 1132, 811; ¹H NMR (500 MHz, CDCl₃) δ : 1.08 (s, 3H, CH₃), 1.22 (s, 3H, CH₃), 2.17–2.36 (dd, 2H, C₉-H), 2.62–2.88 (dd, 2H, C₁₁-H), 5.36 (s, 1H, C₇-H), 7.22–7.80 (m, 10H, Ar-H), 8.60 (d, 1H, *J* = 8.0, C₆-H), 9.27 (s, 1H, NH) ppm; ¹³C NMR (125 MHz, CDCl₃) δ : 26.8, 28.9, 32.0, 34.0, 43.2, 52.1, 67.2, 75.3, 88.7, 107.4, 118.0, 121.1, 122.6, 123.7, 125.0, 126.6, 129.7, 130.4, 132.0, 133.5, 146.8, 154.0, 158.5, 197.0 ppm; MS(ESI): *m/z* 354 (M + H)⁺; Anal. Calcd for C₂₅H₂₃NO: C, 84.99; H, 6.52; N, 3.97%. Found: C, 84.87; H, 6.48; N, 3.92%.



Scheme 1 Preparation of succinimide-*N*-sulfonic acid.

2.4.2. 10,10-Dimethyl-7-(4-dimethylaminophenyl)-9,10,11,12-tetrahydrobenzo[*c*]acridin-8(7*H*)-one (4*b*)

White crystal; IR (KBr, cm^{-1}): 3321, 3066, 2898, 1666, 1577, 1522, 1435, 1140, 815; ^1H NMR (500 MHz, CDCl_3) δ : 1.00 (s, 3H, CH_3), 1.19 (s, 3H, CH_3), 2.22–2.44 (dd, 2H, $\text{C}_9\text{-H}$), 2.55–2.80 (dd, 2H, $\text{C}_{11}\text{-H}$), 2.94 (s, 6H, $\text{N}(\text{CH}_3)_2$), 5.26 (s, 1H, $\text{C}_7\text{-H}$), 7.15–7.77 (m, 9H, Ar-H), 8.77 (d, 1H, $J = 7.6$, $\text{C}_6\text{-H}$), 9.33 (s, 1H, NH) ppm; ^{13}C NMR (125 MHz, CDCl_3) δ : 26.9, 28.8, 31.2, 33.6, 42.6, 52.0, 67.0, 74.7, 88.7, 107.0, 117.8, 120.7, 122.9, 123.5, 124.7, 127.1, 129.5, 130.1, 131.6, 133.5, 147.0, 153.7, 158.2, 196.8 ppm; MS(ESI): m/z 397 ($\text{M} + \text{H}$) $^+$; Anal. Calcd for $\text{C}_{27}\text{H}_{28}\text{N}_2\text{O}$: C, 81.82; H, 7.07; N, 7.07%. Found: C, 81.72; H, 7.02; N, 7.04%.

2.4.3. 10,10-Dimethyl-7-(4-methylphenyl)-9,10,11,12-tetrahydrobenzo[*c*]acridin-8(7*H*)-one (4*c*)

White crystal; IR (KBr, cm^{-1}): 3308, 3080, 2890, 1663, 1572, 1524, 1422, 1146, 822; ^1H NMR (500 MHz, CDCl_3) δ : 1.03 (s, 3H, CH_3), 1.23 (s, 3H, CH_3), 2.12 (s, 3H, CH_3), 2.18–2.48 (dd, 2H, $\text{C}_9\text{-H}$), 2.53–2.78 (dd, 2H, $\text{C}_{11}\text{-H}$), 5.40 (s, 1H, $\text{C}_7\text{-H}$), 7.27–7.90 (m, 9H, Ar-H), 8.64 (d, 1H, $J = 8.0$, $\text{C}_6\text{-H}$), 9.28 (s, 1H, NH) ppm; ^{13}C NMR (125 MHz, CDCl_3) δ : 27.5, 29.1, 31.3, 34.1, 42.7, 52.6, 66.8, 75.0, 89.0, 106.9, 117.6, 121.5, 122.0, 123.7, 124.5, 127.0, 129.1, 129.9, 131.8, 133.5, 146.5, 154.2, 157.8, 196.5 ppm; MS(ESI): m/z 368 ($\text{M} + \text{H}$) $^+$; Anal. Calcd for $\text{C}_{26}\text{H}_{25}\text{NO}$: C, 85.01; H, 6.81; N, 3.81%. Found: C, 84.95; H, 6.77; N, 3.80%.

2.4.4. 10,10-Dimethyl-7-(4-methoxyphenyl)-9,10,11,12-tetrahydrobenzo[*c*]acridin-8(7*H*)-one (4*d*)

White crystal; IR (KBr, cm^{-1}): 3311, 3082, 2884, 1673, 1578, 1516, 1425, 1133, 825; ^1H NMR (500 MHz, CDCl_3) δ : 1.09 (s, 3H, CH_3), 1.21 (s, 3H, CH_3), 2.18–2.39 (dd, 2H, $\text{C}_9\text{-H}$), 2.67–2.89 (dd, 2H, $\text{C}_{11}\text{-H}$), 3.53 (s, 3H, OCH_3), 5.39 (s, 1H, $\text{C}_7\text{-H}$), 7.14–7.84 (m, 9H, Ar-H), 8.70 (d, 1H, $J = 7.6$, $\text{C}_6\text{-H}$), 9.37 (s, 1H, NH) ppm; ^{13}C NMR (125 MHz, CDCl_3) δ : 27.0, 29.5, 31.0, 33.5, 43.0, 52.7, 66.6, 74.6, 88.8, 106.7, 118.1, 120.9, 122.2, 123.4, 124.7, 126.6, 129.0, 129.7, 132.1, 133.5, 147.1, 153.7, 157.9, 196.7 ppm; MS(ESI): m/z 384 ($\text{M} + \text{H}$) $^+$; Anal. Calcd for $\text{C}_{26}\text{H}_{25}\text{NO}_2$: C, 81.46; H, 6.53; N, 3.66%. Found: C, 81.38; H, 6.47; N, 3.60%.

2.4.5. 10,10-Dimethyl-7-(4-chlorophenyl)-9,10,11,12-tetrahydrobenzo[*c*]acridin-8(7*H*)-one (4*e*)

White crystal; IR (KBr, cm^{-1}): 3322, 3060, 2879, 1677, 1560, 1527, 1427, 1142, 810; ^1H NMR (500 MHz, CDCl_3) δ : 1.10 (s, 3H, CH_3), 1.26 (s, 3H, CH_3), 2.24–2.47 (dd, 2H, $\text{C}_9\text{-H}$), 2.72–2.93 (dd, 2H, $\text{C}_{11}\text{-H}$), 5.41 (s, 1H, $\text{C}_7\text{-H}$), 7.11–7.81 (m, 9H, Ar-H), 8.79 (d, 1H, $J = 7.8$, $\text{C}_6\text{-H}$), 9.25 (s, 1H, NH) ppm; ^{13}C NMR (125 MHz, CDCl_3) δ : 27.6, 29.0, 32.1, 33.3, 42.6, 52.3, 66.4, 74.4, 89.3, 107.0, 118.2, 121.1, 122.4, 123.0, 124.6, 126.4, 129.4, 129.9, 131.5, 133.5, 146.6, 153.5, 158.4, 198.1 ppm; MS(ESI): m/z 388 ($\text{M} + \text{H}$) $^+$; Anal. Calcd for $\text{C}_{25}\text{H}_{22}\text{ClNO}$: C, 77.43; H, 5.68; N, 3.61%. Found: C, 77.40; H, 5.63; N, 3.57%.

2.4.6. 10,10-Dimethyl-7-(4-bromophenyl)-9,10,11,12-tetrahydrobenzo[*c*]acridin-8(7*H*)-one (4*f*)

White crystal; IR (KBr, cm^{-1}): 3305, 3079, 2894, 1668, 1564, 1521, 1432, 1146, 816; ^1H NMR (500 MHz, CDCl_3) δ : 1.02 (s, 3H, CH_3), 1.24 (s, 3H, CH_3), 2.13–2.43 (dd, 2H, $\text{C}_9\text{-H}$),

2.67–2.87 (dd, 2H, $\text{C}_{11}\text{-H}$), 5.28 (s, 1H, $\text{C}_7\text{-H}$), 7.20–7.80 (m, 9H, Ar-H), 8.58 (d, 1H, $J = 8.0$, $\text{C}_6\text{-H}$), 9.30 (s, 1H, NH) ppm; ^{13}C NMR (125 MHz, CDCl_3) δ : 27.1, 28.7, 31.5, 33.7, 42.7, 52.2, 67.3, 75.2, 88.5, 107.2, 117.6, 121.5, 122.5, 123.0, 125.2, 126.7, 129.5, 130.2, 131.7, 133.5, 147.4, 153.8, 157.5, 196.5 ppm; MS(ESI): m/z 432.9 ($\text{M} + \text{H}$) $^+$; Anal. Calcd for $\text{C}_{25}\text{H}_{22}\text{BrNO}$: C, 69.46; H, 5.09; N, 3.24%. Found: C, 69.33; H, 5.01; N, 3.22%.

2.4.7. 10,10-Dimethyl-7-(4-fluorophenyl)-9,10,11,12-tetrahydrobenzo[*c*]acridin-8(7*H*)-one (4*g*)

White crystal; IR (KBr, cm^{-1}): 3316, 3071, 2882, 1672, 1574, 1517, 1430, 1138, 821; ^1H NMR (500 MHz, CDCl_3) δ : 1.05 (s, 3H, CH_3), 1.19 (s, 3H, CH_3), 2.12–2.38 (dd, 2H, $\text{C}_9\text{-H}$), 2.59–2.80 (dd, 2H, $\text{C}_{11}\text{-H}$), 5.33 (s, 1H, $\text{C}_7\text{-H}$), 7.16–7.84 (m, 9H, Ar-H), 8.71 (d, 1H, $J = 7.6$, $\text{C}_6\text{-H}$), 9.35 (s, 1H, NH) ppm; ^{13}C NMR (125 MHz, CDCl_3) δ : 26.9, 28.9, 31.3, 34.2, 42.2, 52.0, 67.1, 75.0, 88.6, 107.1, 117.7, 120.8, 122.5, 123.2, 124.6, 126.8, 129.6, 130.2, 131.9, 133.5, 147.3, 154.3, 157.6, 196.7 ppm; MS(ESI): m/z 372 ($\text{M} + \text{H}$) $^+$; Anal. Calcd for $\text{C}_{25}\text{H}_{22}\text{FNO}$: C, 80.86; H, 5.93; N, 3.77%. Found: C, 80.84; H, 5.95; N, 3.76%.

2.4.8. 10,10-Dimethyl-7-(4-hydroxyphenyl)-9,10,11,12-tetrahydrobenzo[*c*]acridin-8(7*H*)-one (4*h*)

White crystal; IR (KBr, cm^{-1}): 3423, 3323, 3059, 2878, 1669, 1575, 1519, 1425, 1146, 814; ^1H NMR (500 MHz, CDCl_3) δ : 1.03 (s, 3H, CH_3), 1.17 (s, 3H, CH_3), 2.15–2.43 (dd, 2H, $\text{C}_9\text{-H}$), 2.63–2.87 (dd, 2H, $\text{C}_{11}\text{-H}$), 5.37 (s, 1H, $\text{C}_7\text{-H}$), 7.19–7.82 (m, 9H, Ar-H), 8.68 (d, 1H, $J = 7.6$, $\text{C}_6\text{-H}$), 9.27 (s, 1H, NH), 9.66 (s, 1H, OH) ppm; ^{13}C NMR (125 MHz, CDCl_3) δ : 27.5, 29.5, 31.7, 33.5, 43.0, 53.0, 66.4, 74.6, 88.8, 106.6, 117.5, 121.2, 122.7, 123.4, 124.5, 127.1, 129.3, 130.5, 132.2, 133.5, 147.5, 154.4, 157.9, 196.9 ppm; MS(ESI): m/z 370 ($\text{M} + \text{H}$) $^+$; Anal. Calcd for $\text{C}_{25}\text{H}_{23}\text{NO}_2$: C, 81.30; H, 6.23; N, 8.79%. Found: C, 81.30; H, 6.23; N, 8.79%.

2.4.9. 10,10-Dimethyl-7-(3-chlorophenyl)-9,10,11,12-tetrahydrobenzo[*c*]acridin-8(7*H*)-one (4*i*)

White crystal; IR (KBr, cm^{-1}): 3315, 3064, 2892, 1672, 1563, 1520, 1423, 1139, 818; ^1H NMR (500 MHz, CDCl_3) δ : 1.11 (s, 3H, CH_3), 1.20 (s, 3H, CH_3), 2.11–2.40 (dd, 2H, $\text{C}_9\text{-H}$), 2.69–2.87 (dd, 2H, $\text{C}_{11}\text{-H}$), 5.42 (s, 1H, $\text{C}_7\text{-H}$), 7.23–7.90 (m, 9H, Ar-H), 8.66 (d, 1H, $J = 8.0$, $\text{C}_6\text{-H}$), 9.28 (s, 1H, NH) ppm; ^{13}C NMR (125 MHz, CDCl_3) δ : 27.1, 29.4, 31.8, 33.3, 43.2, 53.0, 66.3, 74.5, 89.1, 106.5, 117.8, 120.7, 121.9, 123.3, 124.7, 126.5, 129.8, 130.3, 131.6, 133.5, 147.4, 153.8, 158.0, 198.1 ppm; MS(ESI): m/z 388 ($\text{M} + \text{H}$) $^+$; Anal. Calcd for $\text{C}_{25}\text{H}_{22}\text{ClNO}$: C, 77.43; H, 5.68; N, 3.61%. Found: C, 77.39; H, 5.67; N, 3.62%.

2.4.10. 10,10-Dimethyl-7-(3-fluorophenyl)-9,10,11,12-tetrahydrobenzo[*c*]acridin-8(7*H*)-one (4*j*)

White crystal; IR (KBr, cm^{-1}): 3304, 3076, 2887, 1675, 1560, 1523, 1419, 1141, 812; ^1H NMR (500 MHz, CDCl_3) δ : 1.04 (s, 3H, CH_3), 1.18 (s, 3H, CH_3), 2.10–2.33 (dd, 2H, $\text{C}_9\text{-H}$), 2.55–2.80 (dd, 2H, $\text{C}_{11}\text{-H}$), 5.29 (s, 1H, $\text{C}_7\text{-H}$), 7.12–7.78 (m, 9H, Ar-H), 8.70 (d, 1H, $J = 7.6$, $\text{C}_6\text{-H}$), 9.35 (s, 1H, NH) ppm; ^{13}C NMR (125 MHz, CDCl_3) δ : 27.2, 29.1, 31.3, 34.1, 42.6, 52.8, 66.9, 74.3, 89.3, 106.9, 118.3, 121.0, 121.9, 123.7, 124.8, 126.5, 129.5, 130.0, 131.8, 133.5, 146.9, 153.5, 157.7,

196.5 ppm; MS(ESI): m/z 372 ($M + H$)⁺; Anal. Calcd for C₂₅H₂₂FNO: C, 80.86; H, 5.93; N, 3.77%. Found: C, 80.74; H, 5.88; N, 3.73%.

2.4.11. 10,10-Dimethyl-7-(3-bromophenyl)-9,10,11,12-tetrahydrobenzo[*c*]acridin-8(7*H*)-one (4*k*)

White crystal; IR (KBr, cm⁻¹): 3317, 3063, 2887, 1667, 1571, 1520, 1427, 1148, 824; ¹H NMR (500 MHz, CDCl₃) δ: 1.02 (s, 3H, CH₃), 1.21 (s, 3H, CH₃), 2.24–2.46 (dd, 2H, C₉-H), 2.60–2.85 (dd, 2H, C₁₁-H), 5.36 (s, 1H, C₇-H), 7.17–7.83 (m, 9H, Ar-H), 8.63 (d, 1H, *J* = 7.8, C₆-H), 9.26 (s, 1H, NH) ppm; ¹³C NMR (125 MHz, CDCl₃) δ: 26.8, 29.0, 31.5, 33.6, 42.5, 52.6, 66.8, 75.0, 89.0, 107.1, 117.8, 121.3, 122.3, 123.6, 125.0, 126.3, 129.1, 129.6, 132.0, 133.5, 146.8, 153.6, 157.9, 196.3 ppm; MS(ESI): m/z 432.9 ($M + H$)⁺; Anal. Calcd for C₂₅H₂₂BrNO: C, 69.46; H, 5.09; N, 3.24%. Found: C, 69.40; H, 5.05; N, 3.25%.

2.4.12. 10,10-Dimethyl-7-(3-nitrophenyl)-9,10,11,12-tetrahydrobenzo[*c*]acridin-8(7*H*)-one (4*l*)

White crystal; IR (KBr, cm⁻¹): 3320, 3070, 2893, 1675, 1574, 1513, 1434, 1137, 826; ¹H NMR (500 MHz, CDCl₃) δ: 1.09 (s, 3H, CH₃), 1.26 (s, 3H, CH₃), 2.17–2.37 (dd, 2H, C₉-H), 2.64–2.87 (dd, 2H, C₁₁-H), 5.40 (s, 1H, C₇-H), 7.14–7.79 (m, 9H, Ar-H), 8.71 (d, 1H, *J* = 7.6, C₆-H), 9.30 (s, 1H, NH) ppm; ¹³C NMR (125 MHz, CDCl₃) δ: 27.3, 28.9, 31.7, 33.8, 42.9, 52.5, 66.7, 74.9, 88.5, 107.3, 117.5, 121.3, 122.5, 123.5, 124.5, 126.7, 129.1, 129.9, 131.5, 133.5, 147.1, 153.9, 157.6, 196.7 ppm; MS(ESI): m/z 399 ($M + H$)⁺; Anal. Calcd for C₂₅H₂₂N₂O₃: C, 75.38; H, 5.53; N, 7.03%. Found: C, 75.33; H, 5.50; N, 7.02%.

3. Results and discussion

In order to standardize the reaction, 1-naphthylamine (1 mmol), benzaldehyde (1 mmol) and dimedone (1 mmol) were dissolved in 5 mL of ethanol and were stirred at 60 °C without catalyst. The yield was only 18% after 4 h of the reaction (Table 1, entry 1). The reaction was tried with different solvents like methanol, acetonitrile, THF, dichloromethane, 1,4-dioxane and water under similar reaction conditions but no appreciable increment in product yield was observed (Table 1, entries 2–7).

Table 2 Optimisation of temperature using SuSA (4 mol%) as catalyst in EtOH.^a

Entry	Temperature (°C)	Time (h)	Yield (%) ^b
1	40	3.5	66
2	50	2.0	81
3	60	0.5	96
4	70	0.5	94

^a Reaction conditions: benzaldehyde (1 mmol), dimedone (1 mmol) and 1-naphthylamine (1 mmol) in EtOH.

^b Isolated yields.

Table 3 The effect of recyclability of SuSA (4 mol%) catalyst on product 4*a* yield.^a

Entry	Cycle	Time (h)	Yield (%) ^b
1	0	0.5	96
2	1	0.5	94
3	2	0.5	92
4	3	0.5	90

^a Reaction conditions: benzaldehyde (1 mmol), dimedone (1 mmol) and 1-naphthylamine (1 mmol) in EtOH at 60 °C.

^b Isolated yields.

The same reaction was carried out in the presence of a catalytic amount of 1 mol% of SuSA in EtOH at 60 °C. The yield of the product was increased to 46% within 3.0 h. (Table 1, entry 8). Increasing the quantity of the catalyst to 2.0, 3.0 and 4.0 mol% gave the corresponding product in 62%, 79% and 96% yields in 2.0 h, 1.0 h and 0.5 h, respectively. Use of just 4.0 mol% was sufficient to drive the reaction forward. The use of 5.0 mol% of SuSA resulted in the same yield of the product. Hence 4.0 mol% of SuSA was sufficient to catalyze the reaction effectively.

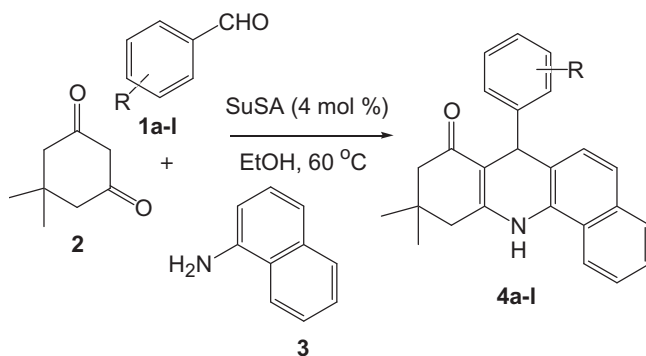
In order to further optimize the yield of the reaction, we tried to perform the experiments in 40, 50, 60 and 70 °C. It was observed that a lower reaction temperature led to a lower yield. As shown in Table 2, entry 3, we found that high temperature could improve the reaction yield and shorten the reaction time. Having these results in hand, we selected the EtOH as solvent for the one-pot reaction of 1-naphthylamine, aromatic aldehyde and dimedone to give corresponding substituted tetrahydrobenzo[*c*]acridine derivatives at 60 °C.

Table 1 The reaction of benzaldehyde, dimedone and 1-naphthylamine: solvent screening and catalyst loading^a.

Entry	Solvent	Amount of SuSA (mol%)	Time (h)	Yield (%) ^b
1	EtOH	–	4.0	18
2	MeOH	–	4.0	13
3	CH ₃ CN	–	4.0	12
4	THF	–	4.0	15
5	CH ₂ Cl ₂	–	4.0	10
6	1,4-Dioxane	–	4.0	16
7	Water	–	4.0	11
8	EtOH	1.0	3.0	46
9	EtOH	2.0	2.0	62
10	EtOH	3.0	1.0	79
11	EtOH	4.0	0.5	96
12	EtOH	5.0	0.5	96

^a Reaction conditions: benzaldehyde (1 mmol), dimedone (1 mmol) and 1-naphthylamine (1 mmol) in different solvents (5 mL) at 60 °C.

^b Isolated yields.



Scheme 2 Synthesis of 10,10-dimethyl-7-phenyl-9,10,11,12-tetrahydrobenzo[*c*]acridin-8-one derivatives **4a-l** by the reactions of aromatic aldehydes with dimedone and 1-naphthylamine.

The reusability of the catalyst is one of the most important benefits and makes it useful for commercial applications. Thus the recovery and reusability of SuSA were investigated. After completion of the reaction, the reaction mixture was cooled to ambient temperature, CH_2Cl_2 was added, and the SuSA was filtered off. The recycled catalyst has been examined in

the next run. The SuSA catalyst could be reused four times without any loss of its activity (Table 3).

We next examined a wide variety of aromatic aldehydes with various substituents to establish the catalytic importance of SuSA for this reaction (Scheme 2). A wide range of aromatic aldehydes undergo this one-pot multicomponent synthesis with 1-naphthylamine and dimedone to afford substituted tetrahydrobenzo[*c*]acridin-8-ones in good yields. In all cases, we observed the almost same performance toward this cyclocondensation to give the desired product (**4a-l**) (Table 4).

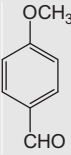
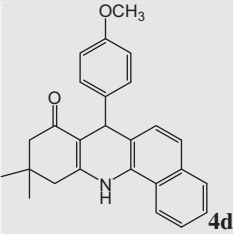
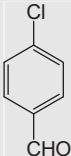
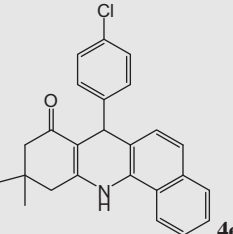
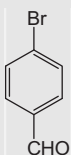
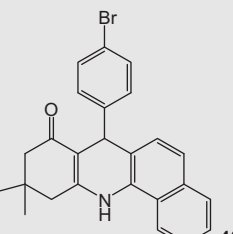
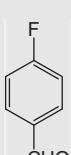
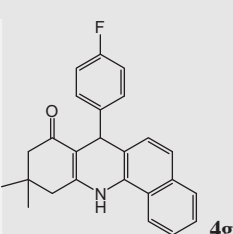
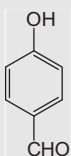
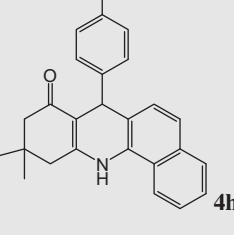
The isolated compounds **4a-l** were completely characterized by IR, ^1H NMR, ^{13}C NMR, mass and elemental analyses. The melting points of the known compounds were in agreement with those of the literature reported. The IR spectra for **4a** exhibited sharp bands at 3312 cm^{-1} (NH), 1672 cm^{-1} (C=O). In the ^1H NMR spectra the two singlet signals around $\delta = 1.08$ and $\delta = 1.22$ ppm correspond to two methyl groups at C-10 in 10,10-dimethyl-7-phenyl-9,10,11,12-tetrahydrobenzo[*c*]acridin-8(7*H*)-one. The singlet signal around $\delta = 5.36$ correspond to methine at C-7. The doublets around $\delta = 2.17\text{--}2.36$ ppm and $2.62\text{--}2.88$ ppm correspond to the presence of two CH_2 at C-9 and C-11. The singlet signal around $\delta = 9.27$ ppm correspond to NH group.

Table 4 Synthesis of various 10,10-dimethyl-7-phenyl-9,10,11,12-tetrahydrobenzo[*c*]acridin-8(7*H*)-one derivatives in the presence of SuSA (4 mol%).^a

Entry	Aldehydes	Product	Time yield		Mp (Lit.) °C
			(h)	(%) ^b	
1			0.5	96	258–260 (258–259) [24]
2			1.0	88	275–277 (276–278) [21]
3			1.0	90	210–212 (212–214) [6]

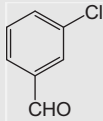
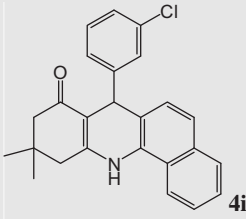
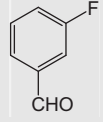
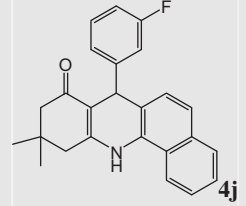
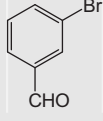
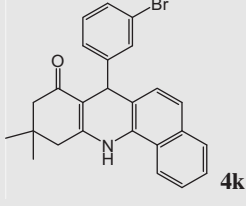
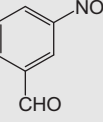
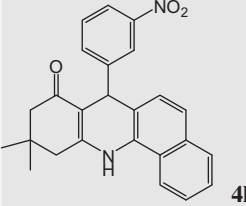
(continued on next page)

Table 4 (continued)

Entry	Aldehydes	Product	Time yield		Mp (Lit.) °C
			(h)	(%) ^b	
4			1.0	91	259–261 (260–262) [24]
5			1.5	95	264–266 (265–266) [21]
6			0.4	94	280–282 (278–280) [21]
7			0.4	95	218–220 (218–219) [6]
8			1.0	92	278–280 (280–282) [24]

(continued on next page)

Table 4 (continued)

Entry	Aldehydes	Product	Time yield		Mp (Lit.) °C
			(h)	(%) ^b	
9			1.0	96	244–246
10			0.4	94	208–210
11			0.4	95	266–268
12			0.4	94	266–268 (267–269) [21]

^a Reaction conditions: substituted benzaldehyde (1 mmol), dimedone (1 mmol) and 1-naphthylamine (1 mmol) in the presence of SuSA (4 mol%) in EtOH at 60 °C.
^b Isolated yields.

4. Conclusions

In summary, an efficient method for the synthesis of 10,10-dimethyl-7-phenyl-9,10,11,12-tetrahydrobenzo[*c*]acridin-8(7*H*)-one derivatives has been developed in the presence of SuSA in EtOH. The products were obtained in excellent yields and the reaction times were significantly short. The present approach demonstrates a simple and appropriate method for the three-component coupling of aromatic aldehydes with dimedone and 1-naphthylamine in order to synthesize some heterocyclic compounds *via* SuSA as a novel, effective and simple reusable catalyst.

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