LETTER ARTICLE



DABCO: An Efficient Catalyst for Pseudo Multi-component Reaction of Cyclic Ketone, Aldehyde and Malononitrile



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Abstract: *Background*: Designing efficient methods for the synthesis of complex molecules with predefined functionalities is a challenging task in modern organic chemistry. In this context, multicomponent reactions (MCRs), by virtue of their applications, constitute a central academic and industrial investigation domain. Recently, MCRs involving vinylogous Michael addition have attracted increasing interest as one of the most useful key reactions for the synthesis of poly substituted benzene derivatives such as spiro[cyclohexanes-1,3'-indoline]-2',3-diones, spiroacenaphthylene, benzo[α]cyclooctenes, *etc.* Therefore, development of an efficient method for a MCR which encompass vinylogous Michael addition as vital reaction is of current interest.

ARTICLE HISTORY

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DOI: 10.2174/1570178614666170426163442 *Methods*: We explored catalytic efficiency of DABCO in the multi-component reaction of cyclic ketone, aldehyde and two moles of malononitrile for the synthesis of functionalized condensed bicyclic compounds *viz* tetrahydroindenes, tetrahydronaphthalenes, hexahydrobenzo[7] annulenes and hexahydrobenzo[8]annulenes.

Results: The reaction conditions were optimized by screening of catalyst and solvent. Employing optimized reaction conditions library of bicyclic compounds *viz*. tetrahydroindenes, tetrahydronaphthalenes, hexahydrobenzo[7]annulenes and hexahydrobenzo[8]annulenes were synthesized in short time duration. The synthesized products were characterized by ¹H, ¹³C, IR and MS. Spectral data obtained was in good agreement with the structure of products.

Conclusion: We disclosed DABCO catalyzed multi-component reaction of aldehyde, cyclic ketone and malononitrile furnished corresponding tetrahydronaphthalenes, tetrahydroindalenes, hexahydrobenzo[7] annulenes and hexahydrobenzo[8]annulenes, with a high level of complexity. Notably, this methodology provides a facile access to various multi-functional compounds. The operational simplicity and good yields, combined with step and atom-economic aspects, clean reactions yielded pure products, hence no requirement of tedious chromatographic purification makes this synthetic strategy highly attractive and promising approach from sustainable and practical chemistry.

Keywords: Aldehyde, DABCO, hexahydrobenzo[7]annulenes, hexahydrobenzo[8]annulenes, multi-component, tetrahydroindenes.

1. INTRODUCTION

Designing of efficient methods for the synthesis of complex molecules with predefined functionalities is a challenging task in modern organic chemistry [1-5]. Especially, when the method involves green principles and simple molecules as starting materials. In this context, multi-component reactions (MCRs), by virtue of their applications, constitute a central academic and industrial investigation domain [6-12]. The last decade has witnessed tremendous development in Michael addition based MCRs as they allow a rapid access to highly functionalized skeleton offering interesting opportunities for molecular diversity [13-15]. Conversely, existence of a variety of intermediates in case of such MCRs makes the prediction of product(s) difficult under different experimental conditions from same precursors [16-18].

Recently, MCRs involving vinylogous Michael addition has attracted increasing interest as one of the most useful key reactions for the synthesis of poly substituted benzene derivatives [19] like spiro[cyclohexanes-1,3'-indoline]-2',3diones [20], spiroacenaphthylene [21], benzo[α]cyclooctenes [22], *etc.* Therefore, the development of an efficient method for MCRs which encompasses vinylogous Michael addition as vital reaction is of current interest.

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2. RESULTS AND DISCUSSION

In continuation of our research program dedicated to designing of multi-component transformations proceed through Michael addition [27-29], in the present manuscript, we described the influence of DABCO on the product of the MCR between aldehyde, two moles of malononitrile and a cyclic ketone *viz*. cyclopentanone, cyclohexanone, cycloheptanone as well as cyclooctanone. The method furnished functionalized condensed bicyclic compounds *viz*. tetrahydroindenes, tetrahydronaphthalenes, hexahydrobenzo[7]annulenes and hexahydrobenzo[8]annulenes, respectively through vinylogous Michael addition (Scheme **2**).

A literature survey of multi-component reaction of aldehyde, two moles of malononitrile and a cyclic ketone reveals that existence of product is dependent on the nature of catalyst used. It is noteworthy that the influence of strong base, LiOEt on present multi-component reaction leads benzo[α] cyclooctenes (4', Scheme 1) which proceed through domino Knoevenagel condensation-Vinylogous Michael addition-Thorpe-Ziegler cyclization-tautomerization-elimination [22]. On the other hand mild catalyst furnished corresponding functionalized condensed bicyclic compounds [23-26] (4, Scheme 1). However, scanty methods are available for present multi-component reaction [22-26]. Hence, we are interested in investigating the effect of a mild base, DABCO on the said transformation.



Scheme (1). Synthesis of functionalized hexahydrobenzo [8] annulenes.

For optimization of the conditions, the reaction between benzaldehyde, cyclooctanone and two moles of malononitrile was selected as a model reaction. The starting materials were mixed together and the reaction was performed using catalytic quantity of DABCO (20 mol %) in ethanol medium at ambient temperature. The reaction yielded a mixture of unidentified products at ambient temperature. However, under reflux conditions, pleasingly we obtained functionalized condensed bicyclic compounds instead of benzo[α]cyclooctenes (Scheme 1). It is noteworthy that, DABCO catalyzed multicomponent reaction of cyclohexanone, aldehyde and two moles of malononitrile also generated a family of functionalized hexahydrobenzo[8]annulenes through Knoevenagel-vinylogous Michael addition. Presumably, such change in the nature of final product of the reaction is due to the difference in basicity of DABCO and LiOEt. The influence of a strong base, LiOEt, resulted into the formation of benzo[α]cyclooctenes while the presence of a mild base, DABCO, furnished functionalized hexahydrobenzo[8]annulenes (Scheme 1).

Added advantage of the present method is that the product can be isolated by simple filtration and purified by washing with EtOH. Therefore, the developed method was simple and involving clean work-up procedure. The product was identified by IR, ¹H, ¹³C NMR and MS. ¹H NMR spectrum indicates a remarkable singlet at $\delta = 4.38$ of vinylic proton. In ¹³C NMR signals due to carbonyl of aldehyde and ketone get disappeared and appearance of signals of nitrile carbons at δ 117.35 and 124.56 confirmed the structure of product 4i (Table **2**). MS analysis also supported the expected structure by demarking molecular ion peak at 328 (m/z).

The reaction was carried out in different solvents to investigate the most suitable solvent for this transformation. Ethanol was found to be superior to other solvents such as CH₃CN, CH₂Cl₂, THF, CH₃OH and H₂O in terms of obtained yield. (Entries 1-6, Table 1) To increase yield, in light with our earlier experience with mixed solvent system [28], we further investigated the effect of ethanol: water system. (Entries 7-15, Table 1). Delightfully, after some attempts, we were pleased to notice that when mixed solvent (7:3 v/v; EtOH:H₂O) was used, the reaction of benzaldehyde, cyclooctanone and two moles of malononitrile provided desired hexahydrobenzo[8]annulenes in 90 % yield in the presence of 20 mol % DABCO at reflux condition. (Entry 9, Table 1) As the reaction proceeds via charged reactive intermediates, we hypothesized that the corresponding transition states would be stabilized by water, which has a relatively high static permittivity ($\varepsilon T = 78.4$) [30], thus small quantity of water played a crucial role.

Then the effect of amount of DABCO was also studied. (Entries **16-19**, Table **1**) Interestingly, 20 mol % of DABCO was found to be effective. Lower loading of DABCO led to shrank yields (Entries **16-18**, Table **1**). Exceeding 20 % of DABCO did not affect the yield of product (Entry **19**, Table **1**).

After optimization of the reaction conditions, to delineate this approach, particularly regarding construction of library, this methodology was evaluated by using various aldehydes (aromatic and heteroaromatic) as well as several cyclic ketones such as cyclopentanone, cyclohexanone, cycloheptanone and cyclooctanone (Table 2).

Interestingly, when cyclic ketones *viz.* cyclopentanone, cyclohexanone, cycloheptanone and cyclooctanone were employed, the products formed were classified as tetrahydroindenes, tetrahydronaphthalenes, hexahydro-2*H*-benzo[7] annulenes and hexahydrobenzo[8]annulenes, respectively. Under optimized reaction conditions all reactions proceed smoothly resulted corresponding products in excellent yields (Scheme **2**).

Furthermore, the reaction in the presence of aromatic aldehydes bearing simple, electron donating as well as electron withdrawing groups also occurred smoothly and corresponding polyfunctionalized bicyclic compounds were in good yields.

Table 1. Optimization of conditions for multi-component reaction of benzaldehyde, cyclooctanone and two moles of malononitrile^a.

Entry	Solvent	DABCO (mol %)	Yield ^b (%)
1	CH ₃ CN	20	
2	DCM	20	
3	THF	20	
4	CH ₃ OH	20	46
5	EtOH	20	75
6	H ₂ O	20	38
7	EtOH:H ₂ O [9:1]	20	82
8	EtOH:H ₂ O [8:2]	20	78
9	EtOH:H ₂ O [7:3]	20	90
10	EtOH:H ₂ O [6:4]	20	75
11	EtOH:H ₂ O [5:5]	20	56
12	EtOH:H ₂ O [4:6]	20	54
13	EtOH:H ₂ O [3:7]	20	47
14	EtOH:H ₂ O [2:8]	20	43
15	EtOH:H ₂ O [1:9]	20	40
16	EtOH:H ₂ O [7:3]	05	55
17	EtOH:H ₂ O [7:3]	10	73
18	EtOH:H ₂ O [7:3]	15	80
19	EtOH:H ₂ O [7:3]	30	90

^aReaction condition: Benzaldehyde (1 mmol), cyclooctanone (1 mmol), malononitrile (2 mmol), catalyst, solvent (5 mL), Time: 1h; ^bIsolated yield.



Scheme (2). Synthesis of combinatorial library of polyfunctionalised bicyclic compounds.

The broad tolerance of functional groups on the aldehydes inspired us to extend the study to dialdehyde such as isophathalaldehyde. We were pleased to find that multi-component reaction of isophathaladehyde, cyclohexanone and two moles of malononitrile under the optimal reaction conditions furnished desired bis-polyfunctionalized tetrahydronaphthalene in high yield (Entry \mathbf{e} , Table $\mathbf{2}$).

The plausible mechanism is depicted in Scheme **3**. Initially, DABCO influenced Knoevenagel condensation of aldehyde and malononitrile as well as cyclic ketone and malononitrile furnished 5 and 6, respectively. Subsequent vinylogous Michael addition of 5 on 6 yielded the desired product (TM) 4 through transition state 7.

Sr. No	Aldehyde 1	Cyclic Ketone 3	Time (h)	Yield ^b (%)
а	R= H	n=1	1	88
b	R=4-C1	n=1	1	90
с	R= 3-MeO, 4-OH	n=1	1	92
d	R= 3,4,5-MeO	n=1	1	90
e	R= 3-CHO	n=1	1	90
f	R=4-MeO	n=0	1	94
g	R=4-MeO	n=2	1	92
h	R=4-Cl	n=2	1	94
i	Thiophene	n=3	1	90
j	R= H	n=3	1	90

Table 2.Synthesis of combinatorial library of polyfunctional-
ized bicyclic compounds by multi-component ap-
proach^a

^aReaction conditions: Aldehyde (1 mmol), cyclic ketone (1 mmol), malononitrile (2 mmol), catalyst (20 mol %), ethanol: water :: 70:30 (5 mL), reflux temperature , ^bIsolated yield.

3. EXPERIMENTAL

3.1. General

IR spectra were recorded on an Agilent cary 630 and Perkin-Elmer FT-IR 783 spectrophotometer. NMR spectra were recorded on a BrukerAC-300 MHz spectrometer in DMSO-d₆ using tetramethylsilane as internal standard. Mass spectra were recorded on a Shimadzu QP2010 GCMS. Elemental analyses were performed on a EURO EA3000 vector model.

3.2. General Procedure

3.2.1. Synthesis of Tetrahydronaphthalenes

A mixture of aldehyde (1 mmol, 1a: 0.102 mL, 2b: 0.140 g, 3c: 0.152 g, 4d: 0.196 g, 5e: 0.134 g), cyclohexanone (1 mmol, 0.103 mL), malononitrile (2 mmol, 0.111 mL) and DABCO (20 mol %, 0.022 g) in EtOH: H_2O (7:3; 5 mL) was stirred at reflux temperature and stirring was continued till completion of the reaction as indicated by TLC.

3.2.2. Synthesis of Tetrahydroindalenes

A mixture of aldehyde (1 mmol, 6f: 0.121 mL), cyclopentanone (1 mmol, 0.088 mL), malononitrile (2 mmol, 0.111 mL) and DABCO (20 mol %, 0.022 g) in EtOH: H₂O



Scheme (3). A plausible mechanism for DABCO catalyzed pseudo multi-component synthesis of polyfunctionalized bicyclic compounds

(7:3; 5 mL) was stirred at reflux temperature and stirring was continued till completion of the reaction as indicated by TLC.

3.2.3. Synthesis of Hexahydrobenzo[7]annulene

A mixture of aldehyde (1 mmol, 7g: 0.121 mL, 8h: 0.140 g), cycloheptanone (1 mmol, 0.118 mL), malononitrile (2 mmol, 0.111 mL) and DABCO (20 mol %, 0.022 g) in EtOH: H_2O (7:3; 5 mL) was stirred at reflux temperature and stirring was continued till completion of the reaction as indicated by TLC.

3.2.4. Synthesis of and Hexahydrobenzo[8]annulenes

A mixture of aldehyde (1 mmol, 9i: 0.093 mL, 10j: 0.102 mL), cyclooctanone (1 mmol, 0.132 mL), malononitrile (2 mmol, 0.111 mL) and DABCO (20 mol %, 0.022 g) in EtOH: H_2O (7:3; 5 mL) was stirred at reflux temperature and stirring was continued till completion of the reaction as indicated by TLC.

After completion of reaction, the precipitated solid was filtered, washed with ethanol (3 mL) and dried over vacuum to afford corresponding product. All the products were characterized by spectral analysis *viz.* IR, ¹H and ¹³C NMR as well as MS.

3.3. Spectral Data of Synthesized Compounds

Entry a, Table 2: Whitish yellow solid; Mp: $238-240^{\circ}$ C; FT-IR-ATR (v_{max} , cm ⁻¹): 3411, 3333, 3225, 2929, 2206, 1641, 1594, 1492, 1448, 1387, 1340, 1270, 1206, 1155, 1099, 1032, 946, 915, 871, 834, 808, 779, 704, 638; ¹H-NMR (300 MHz, DMSO-d₆): δ 0.81-0.89 (q, 1H, *J*= 12, 3 Hz, C5H), 1.50 (s, 1H, C5H), 1.53-1.54 (d, 1H, *J*= 3 Hz, C6H), 1.65-1.68 (s, 1H, C6H), 2.07-2.17 (m, 2H, C7H), 2.71-2.74 (d, 1H, *J*= 12 Hz, C10H), 3.02-3.06 (d, 1H, *J*= 12 Hz, C4H), 5.77 (s, 1H, C8H), 6.55 (s, 2H, C2-NH₂), 7.24-7.47 (m, 5H, ArH) ppm;¹³C-NMR (75 MHz, DMSO-d₆): 21.50(C5), 25.31(C6), 27.34 (C7), 34.70(C10), 43.05(C4), 52.42(C3), 84.32(C8),

112.39 (CN), 116.01(CN), 122.60(CN), 126.85(C1), 128.29 (C'4), 128.94(C'3,C'5), 129.28(C'2,C'6), 132.18(C9), 134.17 (C'1), 142.71(C2) ppm; MS (EI): 300, 272, 209, 91 m/z; CHN analysis calcd for $C_{19}H_{16}N_4$: 75.98 (C), 5.37 (H), 18.65 (N); Found 74.89 (C), 5.15 (H), 18.57 (N).

Entry b, Table 2: Pale yellow solid; Mp: 235-238°C; FT-IR-ATR (v_{max}, cm⁻¹): 3418, 3340, 3251, 3227, 2946, 2932, 2866, 2832, 2212, 1642, 1601, 1493, 1446, 1429, 1391, 1350, 1339, 1278, 1269, 1212, 1163, 1094, 1015, 837, 805, 781, 752, 704, 671; ¹H-NMR (300 MHz, CDCl₃): δ 0.90-1.03(m, 1H, C5H), 1.60-1.70 (m, 2H, C5H,C6H), 1.80 (s, 1H, C6H), 2.28-2.35 (m, 2H, C7H), 2.81-2.89 (m, 1H, C10H), 3.07-3.11 (d, 1H, J= 12Hz, C4H), 4.90 (s, 2H, -NH₂), 6.07-6.08 (t, 1H, J= 3 Hz, C8H), 7.43-7.51 (m, 4H, ArH) ppm, ¹³C-NMR (75 MHz, CDCl₃): 21.72(C5), 25.38 (C6), 27.09(C7), 34.72(C10), 43.44(C4), 51.67(C3), 112.00 (CN), 114.93(CN), 125.91(C1), 127.13(C'2, C'6), 129.82 (C'3, C'5), 132.26(C9), 135.92(C'1, C'4), 140.07(C2) ppm; MS (EI): 334, 209, 127, 125 m/z; CHN analysis calcd for C₁₉H₁₅N₄Cl: 68.16 (C), 4.25 (H), 16.73 (N); Found 68.06 (C), 4.19 (H), 16.51 (N).

Entry c. Table 2: White solid: Mp: 206-210°C: FT-IR-ATR (v_{max}, cm⁻¹): 3463, 3405, 3340, 3241, 2206, 1655, 1599, 1516, 1462, 1433, 1380, 1262, 1214, 1169, 1129, 1103, 1046, 1009, 921, 882, 854, 820, 765, 739, 683, 634; ¹H-NMR (300 MHz, DMSO-d₆): δ 0.80-0.92 (q, 1H, *J*= 12 Hz, C5H), 1.47-1.67 (m, 3H, C5H, C6H), 2.06-2.22 (m, 2H, C7H), 2.69-2.78 (t, 1H, J= 12Hz, C4H), 3.74-3.78 (d, 3H, J= 12 Hz, C'3-OMe), 5.71 (s, 1H, C8H), 6.75-7.10 (m,3H, C'2, C'5, C'6), 7.33 (s, 2H, -NH₂), 9.24 (s, 1H, C'4-OH) ppm; ¹³C-NMR (75 MHz, DMSO-d₆): δ 21.51(C5), 25.35(C6), 27.45(C7), 34.70 (C10), 43.89(C4), 51.32(C3), 56.24(C-OMe), 81.98(C8), 111.27 (CN), 113.05(CN), 113.44(CN), 116.25(C1), 119.87 (C'6), 120.64(C'2), 125.62(C'5), 129.52(C'3), 144.11(C'4), 147.73(C'1), 148.19(C2) ppm; MS (EI): 346, 222, 137, 103, 77 m/z; CHN analysis calcd for C₂₀H₁₈N₄O₂: 69.35 (C), 5.24 (H), 16.17 (N), 9.24 (O); Found 68.90 (C), 5.12 (H), 16.05 (N), 9.93 (O).

Entry d, Table 2: Pale yellow solid; Mp: 210-212°C; FT-IR-ATR (v_{max}, cm⁻¹): 3419, 3334, 3225, 2936, 2866, 2214, 1647, 1599, 1446, 1392, 1341, 1270, 1207, 1159, 1100, 1041, 958, 918, 852, 803, 733, 606; ¹H-NMR (300 MHz, DMSO-d₆): δ 0.85-0.97 (q, 1H, J= 9, 12 Hz, C5H), 1.48-1.72 (m, 3H, C5H, C6H), 2.08-2.23 (m, 2H, C7H), 2.77-2.84 (t, 1H, J= 9Hz, C10H), 3.41-3.45 (d, 1H, J= 12Hz, C4H), 3.76 (s, 3H, -OMe), 3.77 (s, 3H,-OMe), 3.80 (s, 3H, -OMe), 5.73 (s, 1H, C8H), 6.83-6.87 (d,2H, J= 12Hz, C'2, C'6), 7.31 (s, 2H, -NH₂) ppm; ¹³C-NMR (75 MHz, DMSO-d₆): δ 21.41 (C5), 25.33(C6), 27.34(C7), 34.52(C10), 43.41(C-OMe), 51.63 (C-OMe), 56.57(C4), 60.54(C3), 82.11(C8), 104.75 (CN), 110.76 (CN), 112.86(CN), 113.32(C1), 116.58 (C'6), 120.92 (C'2), 129.31 (C'5), 130.59(C'4), 138.42(C'2), 143.99 (C9), 152.96 (C'1), 153.55(C2) ppm; MS (EI): 262, 247, 219, 188, 161 m/z; CHN analysis calcd for C₂₂H₂₂N₄O₃: 67.68 (C), 5.68 (H), 14.35 (N), 12.29 (O); Found 67.56 (C), 5.68 (H), 14.25 (N), 12.51 (O).

Entry e, Table 2: Pale yellow solid; Mp: 216-220°C; FT-IR-ATR (v_{max}, cm⁻¹): 3417, 3339, 3259, 2972, 2940, 2862, 2833, 2249, 2215, 1651, 1600, 1488, 1449, 1394, 1351, 1339, 1269, 1210, 1175, 1154, 1041, 959, 919, 883, 851, 804, 73, 697; ¹H-NMR (300 MHz, DMSO-d₆): δ 0.92-0.96 (m, 2H, C5H), 1.03-1.08 (t, 1H, J= 6Hz, C5H), 1.37-1.68 (m, 7H, C5H, C6H, C7H), 2.16 (m, 5H, C7H, C10H), 2.50-2.67 (m, 3H, C4, C10), 5.73 (s, 1H, C8H), 7.32 (s, 4H, -NH₂), 7.51-7.77 (m, 4H, ArH) ppm; ¹³C-NMR (75 MHz, DMSO-d₆): δ 18.95 (C5), 21.47(C6), 25.25(C7), 34.72(C10), 43.22(C4), 50.48 (C3), 82.19(C8), 112.66(CN), 113.41(CN), 116.56 (CN), 120.91(C1), 125.25(C'3), 127.75(C'4), 128.86(C'2), 129.21 (C'6), 129.59(C'5), 133.32(C9), 135.77(C'1), 143.72(C2) ppm; MS (EI): 522, 495, 468, 378, 376, 209, 167, 140, 104, 91, 81, 55 m/z; CHN analysis calcd for C₃₂H₂₆N₈: 73.54 (C), 5.01 (H), 21.44 (N); Found 68.03 (C), 5.39 (H), 18.87 (N).

Entry f, Table 2: Yellow solid; Mp: 202-205°C; FT-IR-ATR (v_{max}, cm⁻¹): 3409, 3331, 3245, 3045, 3010, 2959, 2935, 2910, 2857, 2842, 2215, 1651, 1613, 1586, 1514, 1474, 1451, 1442, 1394, 1307, 1280, 1256, 1179, 1152, 1119, 1028, 981, 840, 821, 802, 779, 764, 751, 700, 658; ¹H-NMR (300 MHz, DMSO-d₆): δ 1.13-1.26 (m, 1H,C5H), 1.87-1.93 (q, 1H, J= 6, 6 Hz, C5H), 2.25-2.38 (m, 2H, C6H), 3.24 (s, 2H, C4H, C9H), 3.78 (s, 3H, C'4-OMe), 5.51 (s, 1H,C7H), 6.91-6.93 (d, 2H, J= 6 Hz, ArH), 7.24 (s, 2H,-NH₂), 7.36-7.39 (d, 2H, J= 9 Hz, ArH) ppm; ¹³C-NMR (75 MHz, DMSO-d₆): 29.73 (C5), 31.38(C6), 43.24(C9), 44.29(C4), 51.94(C3), 55.38 (C-OMe), 112.33(C7), 112.74(CN), 114.26(CN), 116.05 (CN), 116.55 (C'2, C'6), 120.41(C'3, C'5), 126.25(C'4), 130.87 (C1), 135.17(C8), 146.00(C'1), 160.21(C2)ppm; MS (EI): 316, 289, 121, 91 m/z; CHN analysis calcd for C₁₉H₁₆N₄O: 72.14 (C), 5.10 (H), 17.71 (N), 5.06 (O); Found 71.44 (C), 5.05 (H), 16.71 (N), 6.98 (O).

Entry g, Table 2: White solid; Mp: $208-210^{\circ}$ C; FT-IR-ATR (v_{max} , cm⁻¹): 3442, 3353, 3260, 3222, 3012, 2914, 2843, 2200, 1638, 1611, 1592, 1514, 1443, 1399, 1311, 1285, 1249, 1185, 1121, 1030, 965, 923, 839, 808, 786, 750, 717, 695, 673; ¹H-NMR (300 MHz, CDCl₃): δ 1.28-1.63 (m, 4H, C5H, C6H), 1.73-1.89 (m, 3H,C7H), 2.28-2.40 (m, 2H, C8H), 3.09-3.10 (d, 1H, *J*= 3Hz, C4H, C11H), 3.86 (s, 3H, C'-OMe), 4.94 (s, 1H, -NH₂), 6.21-6.25 (d, 1H, *J*= 6 Hz, C9H), 6.98-

7.01 (d, 2H, J=9 Hz, ArH), 7.37-7.42 (dd, 1H, J=3,3 Hz, ArH) ppm; ¹³C-NMR (75 MHz, CDCl₃): 24.96(C5), 28.30 (C6), 30.41(C7), 31.96(C8), 39.28(C11), 52.95(C4), 55.30 (C-OMe), 87.74(C9), 111.10(C3), 111.79(CN), 114.84(CN), 115.87 (CN), 127.23(C'3, C'5), 130.04(C'2, C'6), 130.17 (C'1, C'4), 133.04(C1), 141.46(C10), 160.62(C2) ppm; MS (EI): 344, 315, 287, 185, 147, 121 m/z; CHN analysis calcd for C₂₁H₂₀N₄O: 73.23 (C), 5.85 (H), 16.27 (N), 4.65 (O); Found 72.89 (C), 5.81 (H), 15.98 (N), 5.32 (O).

Entry h, Table 2: White solid; Mp: 188-190°C; FT-IR-ATR (v_{max} , cm⁻¹): 3632, 3446, 3394, 3342, 2205, 1637, 1620, 1592, 1575, 1523, 1490, 1473, 1440, 1412, 1402, 1017, 958, 918, 852, 803, 733, 606; ¹H-NMR (300 MHz, CDCl₃): δ 1.32-1.55 (m, 4H, C5H, C6H), 1.75-1.85 (m, 4H, C7H, C8H), 2.27-2.43 (m, 2H, C4H, C11H), 4.98 (s, 2H, -NH₂), 6.24-6.27 (t, 1H, *J*= 6 Hz, C9H), 7.44-7.50 (m, 4H, ArH) pm; ¹³C-NMR (75 MHz, CDCl₃): 24.86(C5), 28.26(C6), 30.31 (C7), 32.02(C8), 39.16(C11), 42.38(C4), 52.94(C3), 87.74 (C9), 110.72(CN), 111.39(CN), 115.61(CN), 129.78(C'3, C'5), 130.21(C'2, C'6), 130.51(C'4), 132.38(C'1), 133.85 (C1), 135.91(C10), 141.02(C2) ppm; MS (EI): 348, 294, 223, 160, 127, 125 m/z; CHN analysis calcd for C₂₀H₁₇N₄Cl: 68.86 (C), 4.91 (H), 16.06 (N); Found 68.56 (C), 4.91 (H), 15.51 (N).

Entry j, Table 2: Pale yellow solid; Mp: 225-228°C; FT-IR-ATR (v_{max}, cm⁻¹): 3422, 3308, 3200, 2932, 2911, 2850, 2208, 1644, 1580, 1491, 1471, 1450, 1387, 1357, 1306, 1280, 1206, 1181, 1159, 1039, 1034, 1004, 924, 837, 814, 758, 715, 701, 678; ¹H-NMR (300 MHz, DMSO-d₆): δ 1.33 (s, 1H, C5H), 1.50 (s, 4H, C5H, C6H, C7H), 1.64 (s, 3H, C7H, C8H), 1.81-1.85 (m, 1H, C8H), 2.22-2.30 (m, 1H, C9H), 2.37-2.42 (m, 1H, C9H), 3.72 (s, 2H, -NH₂), 4.38 (s, 1H, C10H), 7.35 (s, 3H, ArH), 7.39 (s, 2H, ArH) ppm; ¹³C-NMR (75 MHz, DMSO-d₆): 25.34(C5), 26.73(C6), 27.99(C7), 29.11(C8), 29.62 (C9), 31.21(C12), 42.26(C4), 51.26(C3), 79.69(C10), 112.01 (CN), 114.83(CN), 117.35(CN), 124.56(C'3, C'5), 126.85 (C'2, C'6), 128.98(C'4), 129.18(C'1), 129.63(C1), 134.43 (C10), 144.40(C2) ppm; MS (EI): 328, 300, 271, 246, 212, 144, 115, 91 m/z; CHN analysis calcd for $C_{21}H_{20}N_4$: 76.80 (C), 6.14 (H), 17.06 (N); Found 76.39 (C), 6.15 (H), 16.60 (N).

CONCLUSION

In conclusion, we disclosed DABCO catalyzed multicomponent reaction of aldehyde, cyclic ketone and malononitrile furnished corresponding tetrahydronaphthalenes, tetrahydroindalenes, hexahydrobenzo[7]annulenes and hexahydrobenzo[8]annulenes, with a high level of complexity. Notably, this methodology provides facile access to various multi-functional compounds. The operational simplicity and good yields, combined with step and atom-economic aspects, clean reactions yielded pure products, hence no requirement of tedious chromatographic purification makes this synthetic strategy highly attractive and promising approach from viewpoint of sustainable and practical chemistry.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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SUPPLEMENTARY MATERIAL

Supplementary material is available on the publisher's website along with the published article.

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