# Facile and Rapid Synthesis of 3,4-Dihydropyrimidin-2(1*H*)-one Derivatives Using $[Et_3NH][HSO_4]$ as Environmentally Benign and Green Catalyst

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**ABSTRACT:** *5-acetyl-6-methyl-4-aryl-3,4-dihydropyrimidin-2(1H)-ones were synthesized in good to excellent by one-pot three-component Biginelli condensation in the presence of ammonium* salt $[Et_3NH][HSO_4]$ *as an inexpensive and green catalyst under solvent-free conditions. High yields, short reaction time, easy work-up, a green environment which requires no toxic organic solvents and reusability of the catalyst are the advantages of this procedure. A broad range of structurally diverse aldehydes (aromatic aldehydes bearing electron withdrawing and electron releasing groups) was applied successfully, and corresponding products were obtained in good to excellent yields without any by-product. In addition, this catalyst was stable during the reaction process and could also be reused several times with consistent activity.*

**KEYWORDS:** *Biginelli reaction; 3,4-Dihydropyrimidin-2(1H)-one; Triethylammonium hydrogen sulfate; Ionic liquid.*



## INTRODUCTION

In recent years, preparation and use of eco-friendly catalysts to improve the efficiency of reactions or provide a higher yield has been the subject of interests especially in the green organic synthesis [1-5]. Ionic Liquids (ILs) play a significant role in green chemistry, especially in organic reactions due to their promising features such as the ability to control product distribution [6], offering enhanced rate [7] and/ or reactivity [8], ease of product recovery [9], catalyst immobilization [10], and recycling [11]. These compounds have also been effectively utilized for the synthesis of novel bioactive compounds [12]. In addition, ILs have very low vapor pressure and are non-explosive and thermally stable in a wide temperature range and can be easily separated from the organic components [13].

3,4-Dihydropyrimidin-2-(1*H*)-ones (DHPMs) and its derivatives have received significant attention in recent years due to their wide range of biological and therapeutic activities such as anti-tumor, anti-bacterial, anti-viral and anti-inflammatory activities [14-17]. Previously different derivatives of 3,4-dihydropyrimidin-2-(1*H*)-ones have exhibited calcium channel modulators, a1a-antagonists and neuropeptide Y (NPY) antagonist [18] The classical Biginelli synthesis is a one-pot condensation

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of aldehydes (aromatic and aliphatic aldehydes), β-ketoester and urea under strongly acidic condition. However, this method involves long reaction times, unsatisfactory yields (20-40%) and harsh reaction conditions [19]. In recent years several methods for the synthesis of DHPMs have been developed to improve and modify this reaction by means of microwave irradiation [20], L-proline [21], $Ce(NO_3)_3$ [22], $Cu(NO_3)_2$ $3H_2O$ [23], Titanium (IV) oxide [24], $Bi(N0_3)_3$ [25], $H_3[PW_{12}O_{40}]$ [26], $Fe_3O_4$(at)Silica sulfuric acid [27], nanomagnetic-supported sulfonic acid [28], FeCl3-supported nanopore silica [29], metal oxide-MWCNTs [30] and nanosilica-supported tin(II) chloride [31].

However, the combination of solvents, toxic reagents, low yields and long reaction times makes some of these previously reported protocols environmentally hazardous. Because of the importance of these compounds, there has been considerable interest to explore, green, rapid, and higher yielding protocol. In continuation of our research on ionic liquids and their applications as catalyst in organic synthesis [32-34], we decided to investigate triethylammonium hydrogen sulfate ($[Et_3NH][HSO_4]$) as a green catalyst for the practical and environmentally benign one-pot three-component synthesis of 5-acetyl-6-methyl-4-aryl-3,4-dihydropyrimidin-2(1*H*)-ones (entries 2-11) under solvent-free conditions (Scheme 1).

## EXPERIMENTAL SECTION

### *General*

Starting materials, solvents, and reagents were either prepared in our laboratories or purchased from Merck, Fluka chemical companies, and used without purification. The products were characterized by their spectral data. IR spectra were recorded by using a BRUKER FT-IR spectrophotometer with KBr plates, $^1H$ and $^{13}C$ NMR spectra were recorded on a Bruker 400-MHz spectrometer in chloroform as a solvent and tetramethylsilan (TMS) as an internal standard. Melting points were recorded on an electrothermal apparatus and were uncorrected. $[Et_3NH][HSO_4]$ was prepared according to a literature method [35].

In all cases, the final products were precipitated out from the reaction mixture and purified by recrystallization.

The catalyst is reusable, due to its insolubility in organic solvents and it displayed high activity which afforded the corresponding products in excellent yield.

### *General procedure for the synthesis of triethylammonium hydrogen sulfate $[Et_3NH][HSO_4]$*

In a 500 ml round-bottomed flask, sulfuric acid (98 g, 1.0 mol) 98% solution in water was dropped into the triethylamine (101 g, 1.0 mol) at 60 °C in 1 hour. After the addition, the reaction mixture was stirred for an additional period of 1 hour at 70 °C to ensure the reaction had proceeded to completion. Then the traces of water was removed by heating the residue at 80 °C in high vacuum (5 mm Hg) until the weight of the residue remained constant.

### *General procedure for the synthesis of 3,4-dihydropyrimidinones*

General procedure: A mixture of aldehyde (1 mmol), acetylacetone (1 mmol), urea (1.2 mmol) and $[Et_3NH][HSO_4]$ (0.5 mmol) under solvent-free conditions was heated to 80 °C for the required time which was monitored by TLC. After completion of the reaction, water (5 mL) was added to the mixture and stirred for 5 min. The solid was filtered for separation of the crude product. The $[Et_3NH][HSO_4]$ was dissolved in water. The separated product was washed twice with water (2×5 mL) and purified by recrystallization in ethanol (96 %). All of the synthesis compounds were characterized by spectral data and comparison of their physical data with the literature. For recycling the catalyst, after washing solid products with water completely, the water containing IL (IL is soluble in water) was evaporated under reduced pressure and IL was recovered and reused.

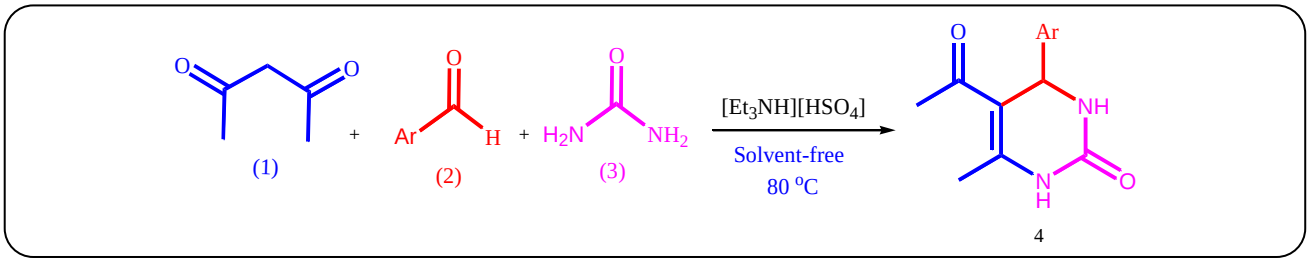
### *Some selected data are as follows*

*5-Acetyl-6-methyl-4-phenyl-3,4-dihydro-1H-pyrimidin-2-one* (entry 1)

IR (KBr): ν= 3257 (NH), 2923 (CH aliph), 1701 (C=O), 1674 (C=O), 1598 (C=C arom), 1238$cm^{-1}$. $^1H$ NMR (400 MHz, $CDCl_3$) δ= 2.15 (s, 3H, $CH_3$), 2.39 (s, 3H, $CH_3$), 5.47 (d, 1H, CH, *J*=2.8 Hz), 5.67 (s, 1H, NH), 7.31-7.39 (m, 5H, CH arom), 7.54 (s, 1H, NH), $^{13}C$ NMR ($CDCl_3$, 100 MHz): δ= 19.7, 30.4, 55.9, 110.5, 126.6, 128.3, 129.1, 142.7, 145.9, 153.1, 195.2.

*5-Acetyl-4-(2-methoxy-phenyl)-6-methyl-3,4-dihydro-1H-pyrimidin-2-one* (entry 2)

IR (KBr): ν= 3264 (NH), 3104 (CH arom), 2945 (CH aliph), 1701 (C=O), 1681 (C=O), 1598 (C=C), 1241 (C-O)$cm^{-1}$.




***Scheme 1: Solvent-free three-component synthesis of 3,4-dihydropyrimidinones using triethylammonium hydrogen sulfate ([Et$_3$NH][HSO$_4$]).***

$^1$H NMR(400 MHz, $CDCl_3$) δ= 2.02 (s, 3H, $CH_3$), 2.29 (s, 3H, $CH_3$), 3.82 (s, 3H, $CH_3$), 5.57 (s, 1H, CH), 6.89 (t, 1H, *J*=7.6 Hz), 7.01-7.05 (m, 2H), 7.24-7.28 (m, 1H), 7.34 (s, 1H, NH), 9.12 (s, 1H, NH), $^{13}$C NMR ($CDCl_3$, 100 MHz): δ= 18.5, 29.6, 48.5, 55.3, 107.7, 111.1, 120.3, 126.7, 128.9, 130.8, 148.0, 152.0, 156.2, 194.5.

*5-Acetyl-4-(4-hydroxy-phenyl)-6-methyl-3,4-dihydro-1H-pyrimidin-2-one* (entry 3)

IR (KBr): ν= 3264 (NH), 3266 (OH), 3103 (NH), 2956 (CH arom), 2817 (CH aliph), 1697 (C=O), 1648 (C=O), 1566 (C=C), 1230 (C=O)cm$^{-1}$. $^1$H NMR (400 MHz, $CDCl_3$) δ= 2.06 (s, 3H, CH3), 2.26 (s, 3H, CH3), 5.14 (s, 1H, CH), 6.70 (d, 2H, *J*=8 Hz), 7.04 (d, 2H, *J*=8Hz), 7.51 (s. 1H, NH), 9.10 (s, 1H, NH), $^{13}$C NMR ($CDCl_3$, 100 MHz): δ= 18.6, 30.0, 53.3, 109.5, 115.0, 127.6, 134.6, 147.4, 151.9, 156.4, 194.5.

*5-Acetyl-4- (4-chloro-phenyl)-6-methyl -3,4-dihydro-1H-pyrimidin-2-one* (entry 5):

IR (KBr): ν= 3287 (NH), 2930 (C-H), 1679 (C=O), 1598 (C=O) cm$^{-1}$. $^1$H NMR (400 MHz, $CDCl_3$) δ= 2.13 (s, 3H, $CH_3$), 2.29 (s, 3H, $CH_3$), 5.26 (s, 1H, CH), 7.25 (d, 2H, *J*=8 Hz), 7.39 (d, 2H, *J*=8 Hz), 7.96 (s, 1H, NH), 9.23 (s, 1H, NH), $^{13}$C NMR ($CDCl_3$, 100 MHz): δ= 18.8, 30.3, 52.8, 109.4, 128.2, 128.4, 131.8, 143.0, 148.3, 151.9, 194.1.

*5-Acetyl-4-(4-methoxy-phenyl)-6-methyl-3,4-dihydro-1H-pyrimidin-2-one* (entry 6)

IR (KBr):ν= 3229 (NH), 3122 (CH arom), 2943 (CH aliph), 1700 (C=O), 1636 (C=O) cm$^{-1}$. $^1$H NMR (400 MHz, $CDCl_3$) δ= 2.07 (s, 3H, $CH_3$), 2.28 (s, 3H, $CH_3$), 3.72 (s, 3H,$CH_3$), 5.20 (s, 1H, CH), 6.88 (d, 2H, *J*=8 Hz), 7.16 (d, 2H, *J*=8 Hz), 7.74 (s, 1H, NH), 9.14 (s, 1H, NH), $^{13}$C NMR ($CDCl_3$, 100 MHz): δ= 18.7, 30.1, 53.1, 55.0, 109.5, 113.8, 127.6, 136.2, 147.6, 151.9, 158.4, 194.4.

## RESULTS AND DISCUSSION

Herein, we describe the utility of [Et$_3$NH][HSO$_4$] as an efficient catalyst in solvent-free conditions for the Biginelli reaction (scheme 1)

To achieve optimum reaction conditions, we initially investigated the one-pot, three-component reaction of acetylacetone, benzaldehyde, and urea as the model reaction under various conditions. This reaction was tested in different protic and aprotic organic solvents, and in the presence of various amount of [Et$_3$NH][HSO$_4$].

The results are presented in Table 1.

These results showed that solvent-free condition at 80°C provided the product in 92% yield after 17 min. (Table 1, entry 12).

Without using the catalyst, the condensation reaction did not proceed until 4 h reflux (Table 1, entry 1).

In the following study on the model reactions, the reactions were examined at various temperatures in the presence of different amounts of [Et$_3$NH][HSO$_4$] in the various solvents (Table 1, entries 2-6) and under solvent-free conditions (Table 1, entries7-14). This observation revealed that the maximum yield of the product in the shortest reaction time was obtained at 80 °C under solvent-free condition.

In order to study the generality of the procedure, a series of DHPMs having different steric and electronic properties were synthesized using the optimized conditions. In all cases, the corresponding 3,4-dihydropyrimidin-2(1*H*)-one derivatives were obtained in good to excellent yields. The results are presented in Table 2.

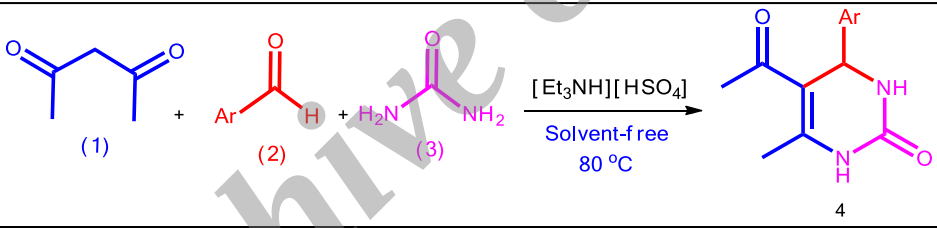
In order to show the merit of the present work, we compared the results of the synthesis of 5-acetyl-6-methyl-4-phenyl-3,4-dihydropyrimidin-2(1*H*)-one (Entry 1 in Table 1) with some previously reported catalysts. The yield of the product in the presence of [Et$_3$NH][HSO$_4$] is comparable to reported catalysts. However, the reaction

***Table 1: Optimization of temperature and amounts of [Et₃NH][HSO₄].***

| Entry | Catalyst Amount (mol%) | Solvent | Temperature (°C) | Time (h) | Yield[a] (%) |
|---|---|---|---|---|---|
| 1 | None | EtOH | reflux | 4 | 0 |
| 2 | $[Et_3NH][HSO_4]$ (30) | $CH_3CN$ | reflux | 2 | 35 |
| 3 | $[Et_3NH][HSO_4]$ (40) | $CHCl_3$ | reflux | 4 | 30 |
| 4 | $[Et_3NH][HSO_4]$ (50) | EtOH | r.t | 2 | 40 |
| 5 | $[Et_3NH][HSO_4]$ (50) | EtOH | reflux | 1 | 60 |
| 6 | $[Et_3NH][HSO_4]$ (50) | THF | reflux | 5 | 35 |
| 7 | $[Et_3NH][HSO_4]$ (50) | None | r.t | 1 | 65 |
| 8 | $[Et_3NH][HSO_4]$ (50) | None | 30 | 55 min | 70 |
| 9 | $[Et_3NH][HSO_4]$ (30) | None | 70 | 30 min | 82 |
| 10 | $[Et_3NH][HSO_4]$ (45) | None | 80 | 23 min | 85 |
| 11 | $[Et_3NH][HSO_4]$ (40) | None | 80 | 27 min | 88 |
| 12 | $[Et_3NH][HSO_4]$ (50) | None | 80 | 17 min | 92 |
| 13 | $[Et_3NH][HSO_4]$ (60) | None | 80 | 17 min | 92 |
| 14 | $[Et_3NH][HSO_4]$ (50) | None | 100 | 17 min | 92 |

*a) Isolated yields.*

***Table 2: Synthesis of 3,4-dihydropyrimidin-2(1H)-ones.***



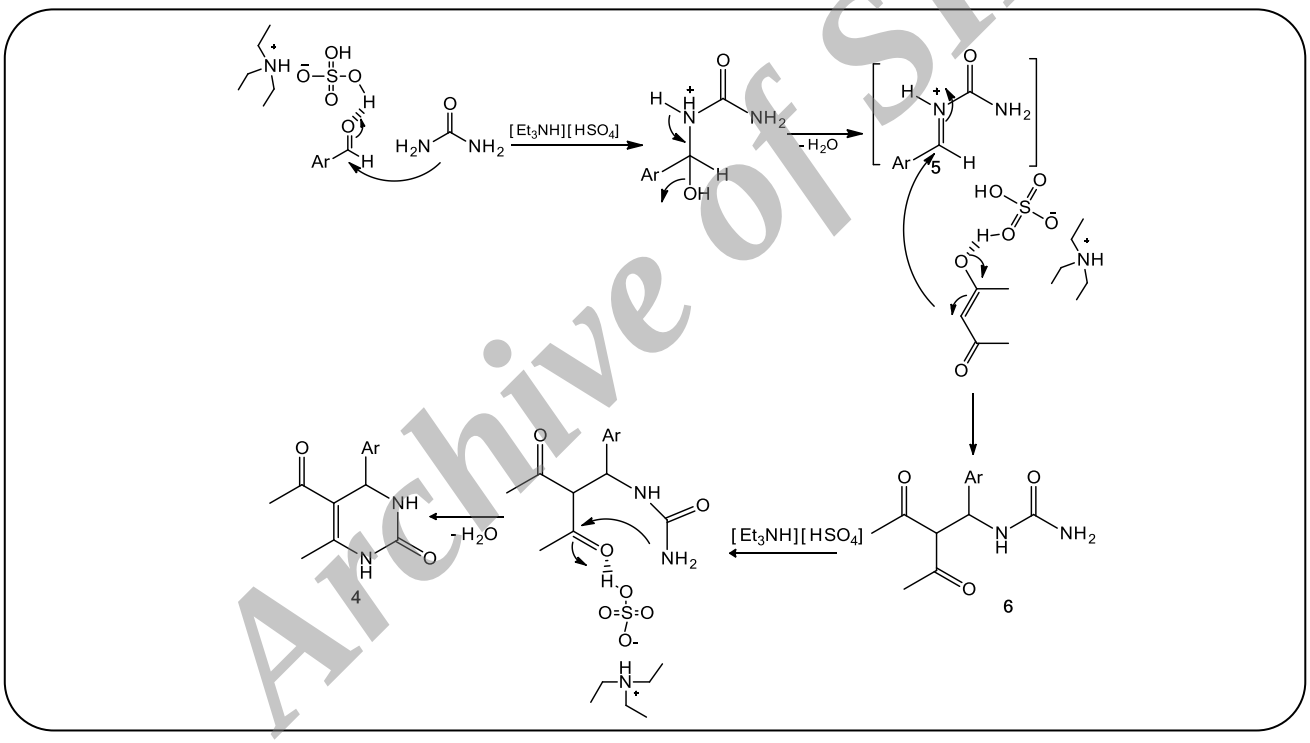

| Entry | Aldehyde | Times (min) | Yield[a] (%) | M.p. (°C) | |
|---|---|---|---|---|---|
| | | | | Found | Reported |
| 1 | PhCHO | ۱۷ | 92 | 235-236 | 234-236 [36] |
| 2 | 2-OMe$C_6H_4$CHO | 20 | 89 | 250-251 | 250-251[38] |
| 3 | 4-OH$C_6H_4$CHO | 15 | 91 | 238-240 | 238-239[23] |
| 4 | 4-Me$C_6H_4$CHO | 18 | 89 | 228-229 | 228-230[39] |
| 5 | 4-Cl$C_6H_4$CHO | ۱۵ | 92 | 210-211 | 210-211[40] |
| 6 | 4-MeO$C_6H_4$CHO | 16 | 90 | 181-182 | 180-182[41] |
| 7 | 2,4-Cl,Cl$C_6H_3$CHO | 22 | 98 | 197-200 | 198-200[23] |
| 8 | 4-BrN$C_6H_4$CHO | 15 | 93 | 239-240 | 238-240 [42] |
| 9 | 2-$O_2$N$C_6H_4$CHO | ۲۱ | 95 | 228-230 | 229-230[25] |
| 10 | 3-$O_2$N$C_6H_4$CHO | 13 | 94 | 288-289 | 287-289[23] |
| 11 | 4-$O_2$N$C_6H_4$CHO | 15 | 93 | 232-235 | 233-235 [36] |

*a) Isolated yields.*

***Table 3: Comparison of the results of the synthesis of 5-acetyl-6-methyl-4-phenyl-3,4-dihydropyrimidin-2(1H)-one with different reported catalysts.***

| Entry | Catalyst (mol %) | Temperature | Time | Yield[a] % [ref] |
|---|---|---|---|---|
| | $Ph_3P$ (10%) | 100 ºC | 10h | 62[43] |
| 1 | L-proline (10%) | r.t | 2h | 91[44] |
| 2 | $P_2O_5$ (10%) | reflux | 1.2h | 91[45] |
| 3 | $H_2SO_4$, silica gel (30 %) | 60 ºC | 2h | 89[46] |
| 4 | $MgBr_2$ (10%) | 100 ºC | 1h | 88[47] |
| 5 | $B_2O_3/Al_2O_3$ (15%) | 75 ºC | 6h | 87[48] |
| 6 | $[(CH_2)_2COOHHmim][HSO_4]$ (1.5%) | 75 ºC | 1h | 85[49] |
| 7 | $H_4SiW_{12}O_{40}*xH_2O$ (2 %) | reflux | 6h | 84[50] |
| 8 | $ClCH_2COOH$ (10 %) | 90 ºC | 3h | 88[51] |
| 9 | $[Et_3NH][HSO_4]$ (50%) | 80 ºC | 17 min | 92(This work) |

*a) Isolated yields.*




***Scheme 2: The proposed mechanism for the synthesis of dihydropyrimidinones using $[Et_3NH][HSO_4]$.***

in the presence of these catalysts required longer reaction times than this work (Table 3).

The proposed mechanism for the synthesis of 3,4-Dihydropyrimidin-2(1*H*)-one Derivatives using $[Et_3NH][HSO_4]$ is shown in scheme 2. Firstly, we assumed that the reaction of the aldehydes and urea generates an acylimine intermediate (5). Interception of this iminium ion intermediate by activated 1,3-dicarbonyl compound produces an open-chain ureide (6) which subsequently undergoes cyclization and dehydration to afford the corresponding dihydropyrimidinone (4).

Finally, we investigated the possibility of recycling of $[Et_3NH][HSO_4]$ using the model reaction forming 5-acetyl-6-methyl-4-phenyl-3,4-dihydro-1H-pyrimidin-2-*one*. After reaction completion, water (5 mL) was added to the mixture, stirred for 5 min and the solid was filtered.

***Table 4: Recycling yields[a].***

| No of Cycles[a] | Fresh | Run 1 | Run 2 | Run 3 |
|---|---|---|---|---|
| Yield[b] | 92 | 89 | 87 | 86 |
| Time (min) | 17 | 16 | 15 | 15 |

*a) Reaction condition: benzaldehyde (1 mmol), acetylacetone (1 mmol), urea (1.2 mmol) and [$Et_3NH$][$HSO_4$] (0.5 mmol).*
*b) Yields refer to pure isolated yields.*

After washing solid product with water (2×3 mL) completely, the aqueous layer containing the catalyst ([$Et_3NH$][$HSO_4$] is soluble in water) was evaporated under reduced pressure and catalyst was recovered and reused for subsequent reactions. The recovered catalysts were reused three runs with only moderate (about 10%) loss in their activity (Table 4).

## CONCLUSIONS

In summary, a simple, efficient and practical approach for the synthesis of dihydropyrimidinone derivatives by the three-component Biginelli condensation reaction of aldehydes with acetylacetone and urea in the presence of [$Et_3NH$][$HSO_4$] as an eco-friendly catalyst under solvent-free conditions was reported. The catalyst is recyclable (up to three times) without significant loss of activity. The main advantages of this methodology are: shorter reaction times; higher yields; free of organic solvent, and easy synthetic procedure.

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