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A Green Synthetic Strategy for Pyrazolo[1,5-*a*]pyrimidin-7(4*H*)-one Derivatives by the Reaction of Aminopyrazoles and Symmetric/Non-symmetric Alkynes Assisted by $KHSO_4$ in Aqueous Media

Susma Das[1], Tara Rangrime A. Sangma[1], Labet Bankynmaw Marpna[1], Jai N. Vishwakarma[1*]

[1] Organic Research Laboratory, Department of Chemistry, Assam Don Bosco University, Tapesia Gardens, 782402 Sonapur, Assam, India
[*] Corresponding author, e-mail: jnvishwakarma@dbuniversity.ac.in

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Abstract

Pyrazolo[1,5-*a*]pyrimidine and its derivatives possess important pharmacological properties and hence they have drawn substantial attention as a privileged scaffold to design and explore novel drugs in medicinal chemistry. We herein report a green synthetic approach for a library of pyrazolo[1,5-*a*]pyrimidin-7(4*H*)-one derivatives under ultrasonic irradiation which is one of the green approaches to minimize environmental impact in synthetic organic chemistry.

Aminopyrazoles were reacted with symmetric and non-symmetric alkynes assisted by $KHSO_4$ under the influence of US in aqueous ethanol to give pyrazolo[1,5-*a*]pyrimidines in good yields. This strategy worked well with dimethyl acetylenedicarboxylate (DMAD) and ethyl/methyl propiolate and the corresponding products were obtained in good yields. The structures of the products were well established with the help of their analytical and spectral data (^{1}H NMR, ^{13}C NMR, FT-IR, MS).

Keywords

alkynes, pyrazolo[1,5-*a*]pyrimidine, $KHSO_4$, ultrasound waves

1 Introduction

Pyrazolo[1,5-*a*]pyrimidine derivatives are important class of heterocyclic compounds possessing a number of biological properties. The use of its derivatives as a foundation for creating drug-like candidates has demonstrated a variety of therapeutic qualities, including anticancer [1], sedative [2], anti-inflammatory [3], antiviral [4], antibacterial [5], analgesic [6], antimicrobial [7], antitumoral [3, 8–10], anxiolytic [11], antischistosomal [12], selective kinase inhibitors [13–15] and HIV reverse transcriptase inhibitors [16]. Pyrazolo[1,5-*a*]pyrimidine derivatives were reported to show impaired cell survival in HCT-116 colorectal carcinoma cell line [9]. The computational examination of diverse pyrazolo[1,5-a]pyrimidines against 3CLpro SARS-COV-2 has unveiled their promising capability to impede and disrupt the replication and maturation processes of Chymotrypsin-like protease of SARS-Coronavirus 2 [17].

Due to their significant role and immense applications, various methodologies for their synthesis have emerged diversely in the field of medicine and chemistry. The establishment of pyrazolo[1,5-*a*]pyrimidine is accomplished by condensing 3 or 5-aminopyrazoles with enaminones [18, 19] formyl ketones [20], 1,3-diketones [21, 22], acetoacetanilides [23] etc. Most of these reactions were carried out using conventional methods such as heating or refluxing with catalysts like ceric ammonium nitrate in ethanol [24], $Cu(OAc)_2$, bipyridine in 1,2-dichlorobenzene [25], ammonium acetate and piperidine in acetic acid [26]. Over the last few decades there has been a transition from conventional methods to green synthetic methods in order to avoid the use of harsh reaction conditions like high temperature, prolonged reaction time, mineral acids, transition metal catalysts, toxic solvents, or volatile organic compounds that contributes to environmental toxicity. For these reasons, researchers have adopted sustainable and eco-friendly approaches that employs microwave [27, 28] and ultrasound [29] irradiation operating under mild solvents, solvent-free or catalyst free conditions [27] and the reactions in aqueous media [30, 31].

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These methods aim to make the synthesis more reliable by reducing energy consumption, minimizing the use of harsh chemicals, and optimizing reaction conditions for improved efficiency and environmental impact leading to higher reaction rates and better yields.

The synthesized compounds have been analyzed for their potential pharmacological properties. Fig. 1 shows the structures of some of the commercial medicines with pyrazolo[1,5-*a*]pyrimidine moiety, such as zaleplon (insomnia), indiplon (hypnotic and sedative) [32], ocinaplon (anxiolytic, sedative and amnestic) [33], pyrazophos (fungicide and insecticide) [34], dinaciclib (melanoma and pancreatic cancer) [35] and dorsomorphin (bone and cartilage) [36].

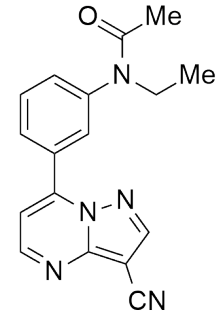
Symmetric and non-symmetric acetylenes have widely been used to synthesize heterocyclic systems such as triazolo[1,5-*a*]pyrimidines [37, 38], quinolinyl-indole/naphtha-oxazepine [39, 40], tetrahydropyrimidines [41], coumarin-4-sulfonate [42], pyrrolophthalazine [43], thioethers [44], spirocyclic oxazines [45], pyrroles [46], tetrahydroquinolines [47], pyrazolopyrimidines [48] and so on. In recent years, the reactions of acetylene derivatives with aminopyrazoles have garnered significant attention in the field of synthetic organic chemistry due to their unique reactivity and versatility [38, 48].

In the light of the importance of this class of compounds, our research group has also reported on the synthesis and biological properties of pyrazolo[1,5-*a*]pyrimidine derivatives [49–51] and molecular hybrids thereof [52–54]. In continuation with these studies, we herein present the synthesis of some novel pyrazolo[1,5-*a*]pyrimidine derivatives by the reaction of 5-aminopyrazoles with acetylenic esters assisted by $KHSO_4$ in aqueous media under the influence of ultrasound waves.

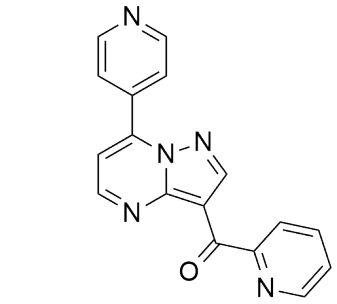
2 Results and discussion

We selected three acetylene derivatives, namely, dimethyl acetylenedicarboxylate (DMAD), methyl propiolate and ethyl propiolate and six 3-aminopyrazole derivatives for the synthesis of the target molecules assisted by $KHSO_4$ in aqueous media under ultrasound irradiation.

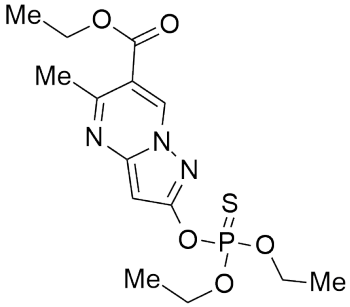
Some commercially available alkyl/aryl/cyano substituted 3-amino-1H-pyrazoles **1** were reacted with DMAD **2a**,



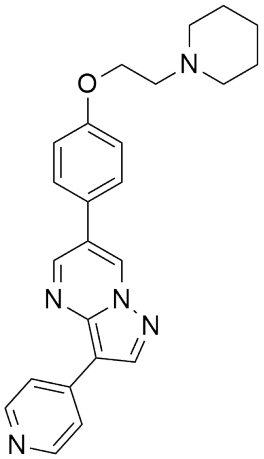
Zaleplon (insomnia)



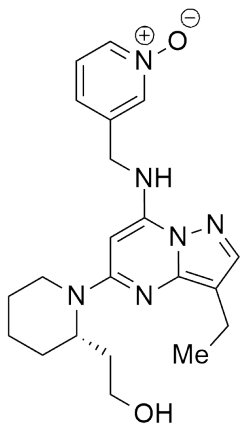
Ocinaplon (anxiolytic, sedative and amnestic)



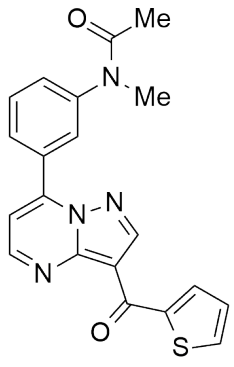
Pyrazophos (fungicide and insecticide)



Dorsomorphin (bone and cartilage)



Dinaciclib (melanoma, pancreatic cancer)



Indiplon (hypnotic and sedative)

Fig. 1 Some commercial drugs having pyrazolo[1,5-*a*]pyrimidine moiety

methyl propiolate **2b** or ethyl propiolate **2c** in presence of $KHSO_4$ under ultrasonic irradiation. The use of an aqueous-alcohol medium was ideal to achieve the desired conversion. We herein report a successful synthesis of functionally diverse pyrazolo[1,5-*a*]pyrimidin-7(4*H*)-ones (**3**).

2.1 Synthesis of 2 or/and 3-substituted methyl 7-oxo-4,7 dihydropyrazolo[1,5-*a*]pyrimidine-5-carboxylate (3a-e)

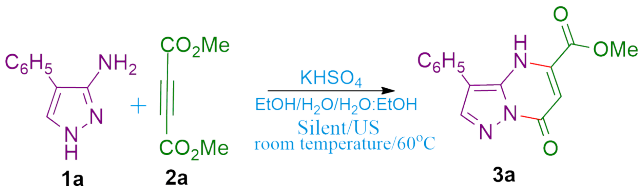
In order to optimize the reaction conditions for the synthesis of the target molecules we selected the reaction between 3-amino-4-phenylpyrazole (**1a**) and DMAD (**2a**) as a model case and carried out a series of reactions under various conditions as presented in the Table 1.

Table 1 clearly shows that carrying out the reactions between **1a** and **2a** in ethanol-water (1:1) under US irradiation at 60 °C gives the best result and hence, we used these conditions for all the reactions in the present study.

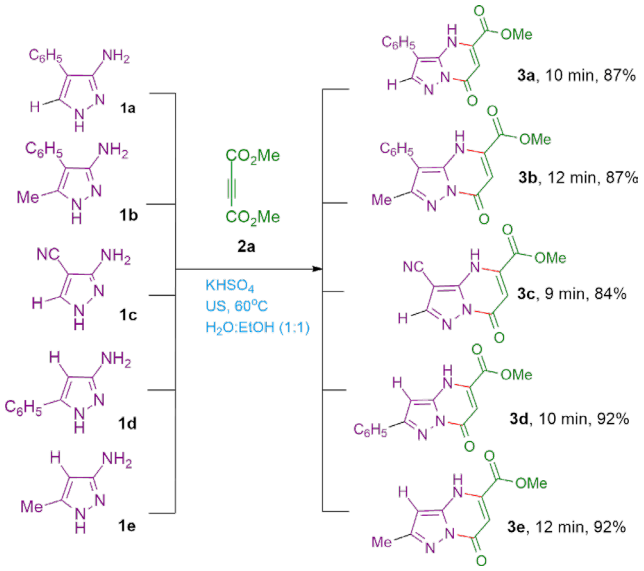
Thus, when an equimolar mixture of **1a** and **2a** taken in ethanol-water mixture was treated with $KHSO_4$ under ultrasound (US) irradiation at 60 °C, the product **3a** precipitated out (Scheme 1). This was collected by filtration and washed repeatedly by water to remove traces of acid giving practically pure product, the structure of which was well established with the help of analytical and spectral data.

As can be seen from Table 1, that water-ethanol solvent mixture produced the best results under sonication. Thus, we chose this route to expand the series and 3-amino-1*H*-pyrazoles **1b-e** were reacted with DMAD **2** under identical conditions (Scheme 2). The products were obtained in 84–92% yields in 9–12 min (Table 2).

Thus, in the ^{1}H NMR spectrum of compound **3a**, the protons of O-CH_3 group were found to resonate at 3.87 ppm as a singlet and the NH proton of it also resonated as a singlet at 4.46 ppm. A singlet for C_6-H and another for C_2-H were seen at 7.91 and 8.87 ppm, respectively. The five aromatic protons of the phenyl group were found resonating as a multiplet in the range of 7.17–7.69 ppm. The ^{13}C NMR spectrum of the compound has all the expected peaks with appropriate chemical shifts, with the most characteristic



Scheme 1 Optimization of reaction conditions



Scheme 2 Synthesis of 2 or/and 3-substituted methyl 7-oxo-4,7-dihydropyrazolo[1,5-*a*]pyrimidine-5-carboxylate

Table 1 Results of the reaction optimization

Entry	Sonication	Temperature (°C)	Solvent	Reaction time	Yield (%)
1	No	Room temperature	Water	6–7 h	No reaction
2	No	Room temperature	Ethanol	6 h	37
3	No	Room temperature	Water-ethanol (1:1)	5 h	52
4	No	80	Water	7 h	No reaction
5	No	80	Ethanol	3 h	62
6	No	80	Water-ethanol (1:1)	45 min	35
7	Yes	Room temperature	Water	6 h	Poor conversion
8	Yes	Room temperature	Ethanol	45 min	65
9	Yes	Room temperature	Water-ethanol (1:1)	30 min	70
10	Yes	60	Water	6 h	19
11	Yes	60	Ethanol	15 min	80
12	Yes	60	Water-ethanol (1:1)	9 min	86

Table 2 Summary of all the synthesized pyrazolo[1,5-*a*]pyrimidine derivatives **3a-k** at 60–65 °C

Product	Time (min)	M. p. (°C)	Yield %	Yield % (after column)
3a	10	156–157	87	72
3b	12	177–178	87	73
3c	9	228–230	84	70
3d	10	247–248	92	81
3e	12	186–187	92	80
3f	12	133–134	77 (2b), 75 (2c)	64
3g	10	163–164	79 (2b), 77 (2c)	63
3h	10	137–139	93	85
3i	12	142–144	85	72
3j	15	162–163	84	73
3k	10	145–146	95	84

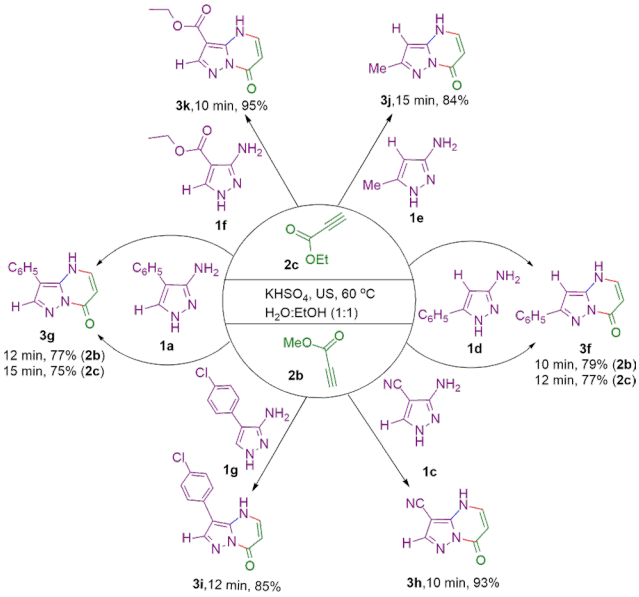
peaks due to the carbonyl carbon atoms appearing at high chemical shifts of 159.3 and 162.2 ppm. The IR spectrum of the compound showed bands at 3244, 1655 and 1622 cm^{-1} due to NH and carbonyl groups respectively [55]. The mass spectrum of the compound with a signal at 270 for $[MH]^+$ was supportive of the proposed structure. The spectra of the compounds **3b-e** showed similar spectral patterns.

2.2 Synthesis of pyrazolo[1,5-*a*]pyrimidin-7(4*H*)-one (3f-k)

Encouraged by the above results, we replaced DMAD **2a** by a non-symmetric alkyne; methyl propiolate **2b** reacted with an equimolar amount of 2 or/and 3-substituted 3-amino-1*H*-pyrazole **1a,c,d,g** under similar conditions (Scheme 3). The products precipitated out and were isolated in 77–93% overall yields by simple filtration in practically pure form (Table 2). The ^{1}H NMR, ^{13}C NMR, FT-IR and MS were found to be in agreement with the proposed structures.

In order to further test the efficacy of the methodology we examined the reactions of a few selected aminopyrazoles **1a** and **1d** with ethyl propiolate **2c** and interestingly the respective pyrazolopyrimidines obtained were found to have spectral and analytical data identical with the ones obtained by their reaction with methyl propiolate. In addition, the reactions of ethyl propiolate with aminopyrazoles **1e** and **1f** were successful under identical conditions to give the products **3j** and **3k** in 84 and 95% yields, respectively (Table 2).

Thus, in the ^{1}H NMR spectrum of **3f**, the NH proton appeared as a singlet at 4.26 ppm. The C_6-H and C_5-H protons exhibited a couple of doublets at 7.12 and 8.93 ppm respectively with a coupling constant of 7.2 Hz. The protons of the phenyl group attached at C_2 gave a multiplet of five protons as expected in the region of 7.24–8.46 ppm.



Scheme 3 Synthesis of a 2 or/and 3-substituted pyrazolo[1,5-*a*] pyrimidine-7(4*H*)-one

The C_3-H proton appeared as a singlet at 6.62 ppm. The ^{13}C NMR spectrum of the compound showed all the C-atoms with expected chemical shift values with the most characteristic carbonyl carbon peak appearing at 155.7 ppm. The IR spectrum of the compound showed absorption band at 3232 cm^{-1} for NH and 1653 cm^{-1} for carbonyl group. The rest of the compounds of the group **3g** to **3i** showed spectral data supportive of proposed structures very well.

On the other hand, ^{1}H NMR spectrum of the product **3j** displayed singlets at 1.32, 4.16 and 6.61 ppm due to CH_3, NH and C_3-H protons respectively. In addition, C_6-H and C_5-H protons resonated as doublets at 7.25 and 8.63 ppm respectively with a coupling constant 7.2 Hz. In ^{13}C NMR spectrum of the compound, expected peaks

were observed. The product **3k** showed identical spectral pattern except for the presence of an ethyl group which exhibited a triplet at 1.43 ppm and a quartet 4.46 ppm with a coupling constant of 6.8 Hz.

2.3 Plausible mechanism

A plausible mechanism for the formation of the target molecules **3** could be rationalized as presented below. In this, the carbonyl oxygen of the ester is protonated by $KHSO_4$, thus facilitating an aza-Michael addition reaction of the aminopyrazole which finally loses a methoxy group resulting in the formation of the proposed pyrazolopyrimidine ring system (Fig. 2).

3 Conclusion

In summary, we have reported herein an efficient synthetic strategy for the preparation of pyrazolo[1,5-*a*]pyrimidines by the reaction of aminopyrazoles with dimethyl acetylenedicarboxylate, methyl propiolate and ethyl propiolate in aqueous media in the presence of $KHSO_4$ assisted by US irradiation. This protocol is advantageous because of its simplicity, good yields, short reaction times, easy isolation and environment friendliness. This method has the potential to be generalized for the synthesis of large libraries of this class of compounds.

4 Experimental

The melting points of each of the synthesized compounds **3a-k** were recorded by the open capillary method and are uncorrected. The ^{1}H NMR and ^{13}C NMR spectra were recorded using DELTA JEOL 400 MHz and BRUKER 400 MHz using $(Me)_4Si$ as the internal standard in chloroform-d. Chemical shift (δ ppm) and coupling constants (Hz) are reported in the standard manner. The abbreviations s, d, dd, t, and m stand for singlet, doublet, double-doublet, triplet, and multiplet respectively. The electron spray mass spectrum was recorded on a THERMO FINNIGAN LCQ Advantage max ion trap mass spectrometer. The FT-IR spectral of the entire compounds were recorded on Perkin-Elmer SPECTRUM TWO. US irradiation was carried out in an EQUITRON Digital Ultrasonic cleaner 2.5-litre, model number 8425.025.424 at 170 watts and 50 Hz.

4.1 General procedure for the synthesis of 2 or/and 3-alkyl/aryl/cyano methyl-7-oxo-4,7-dihydropyrazolo[1,5-*a*]pyrimidine-5 carboxylate (3a-e)

A mixture of pyrazole **1** (0.5 mmol) and DMAD **2a** (0.5 mmol) was dissolved in 2 mL of ethanol in a round bottom flask. To this a solution of $KHSO_4$ (1 mmol) in 2 mL of water was added in one lot and the resulting mixture was irradiated under ultrasonic waves at 60 °C for 9–12 min when a precipitate was formed. On completion of the reaction (TLC), the solid was collected by filtration, washed repeatedly with water and dried to give **3a-e** in 84–92% overall yields in practically pure state. Further purification of the product for spectral and analytical studies, column chromatography (CC) was performed using silica gel (100–200 mesh) and 15% ethyl acetate-hexane. The yields of the purified products were obtained in 70–81%. The analytical and spectral data for the compounds so prepared have been presented below.

4.1.1 Methyl 7-oxo-3-phenyl-4,7-dihydropyrazolo[1,5-*a*] pyrimidine-5-carboxylate (3a)

Off-white solid; yield 0.118 g (87%); CC: yield 0.097 g (72%); m.p.: 156-157 °C; ^{1}H NMR (400 MHz, $CDCl_3$)

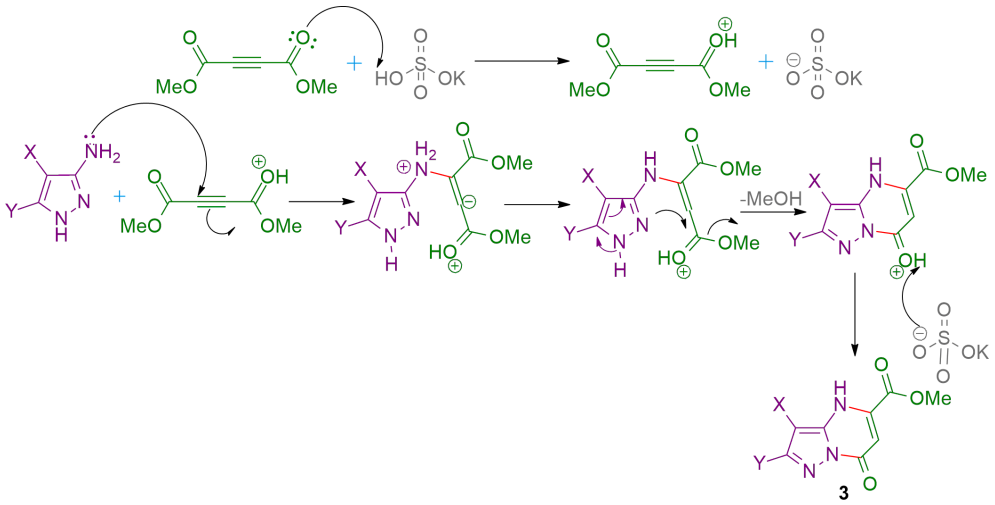


Fig. 2 Mechanism for the formation of product **3**

δ: 3.87 (s, 3H, OCH_3), 4.46 (s, 1H, NH), 7.17–7.69 (m, 5H, C_6H_5), 7.91 (s, 1H, C_6-H), 8.87 (s, 1H, C_2-H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 50.2, 102.8, 119.2, 126.4, 129.3, 130.8, 132.2, 141.8, 149.3, 158.3, 159.3, 162.2; FT-IR (KBr): *ν*/cm^{-1} = 3244 (NH), 1655 (CO_2Me), 1622 (CO); MS (ESI): m/z = 270 (MH^+).

4.1.2 Methyl 2-methyl-7-oxo-3-phenyl-4,7-dihydropyrazolo[1,5-*a*]pyrimidine-5-carboxylate (3b)

Pale yellow solid; yield 0.124 g (87%); CC: yield 0.104 g (73%); m.p.: 177–178 °C; ^{1}H NMR (400 MHz, $CDCl_3$) *δ*: 2.18 (s, 3H, CH_3), 3.87 (s, 3H, OCH_3), 4.26 (s, 1H, NH), 6.23 (s, 1H, C_6-H), 7.13–7.91 (m, 5H, C_6H_5); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 15.8, 51.2, 100.0, 118.3, 126.4, 129.3, 131.3, 132.2, 142.8, 143.3, 158.3, 159.3, 162.2; FT-IR (KBr): *ν*/cm^{-1} = 3244 (NH), 1652 (CO_2Me), 1616 (CO); Anal. Calcd. for $C_{15}H_{13}N_3O_3$: C, 63.60; H, 4.63; N, 14.83. Found C, 63.81; H, 4.62; N, 14.80.

4.1.3 Methyl 3-cyano-7-oxo-4,7-dihydropyrazolo[1,5-*a*]pyrimidine-5-carboxylate (3c)

Pale brown solid; yield 0.092 g (84%); CC: yield 0.079 g (70%); m.p.: 228–230 °C; ^{1}H NMR (400 MHz, $CDCl_3$) *δ*: 3.77 (s, 3H, OCH_3), 4.46 (s, 1H, NH), 6.46 (s, 1H, C_6-H), 8.11 (s, 1H, C_2-H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 50.2, 71.8, 119.2, 120.2, 126.4, 129.3, 139.3, 141.8, 158.3, 159.3, 162.2; FT-IR (KBr): *ν*/cm^{-1} = 3156 (NH), 2231 (CN), 1715 (CO_2Me), 1597 (CO); MS (ESI): m/z = 219 (MH^+).

4.1.4 Methyl 7-oxo-2-phenyl-4,7-dihydropyrazolo[1,5-*a*]pyrimidine-5-carboxylate (3d)

Pale brown solid; yield 0.124 g (92%); CC: yield 0.108 g (81%); m.p.: 247–248 °C; ^{1}H NMR (400 MHz, $CDCl_3$) *δ*: 3.76 (s, 3H, OCH_3), 4.56 (s, 1H, NH), 6.53 (s, 1H, C_6-H), 6.80 (s, 1H, C_3-H), 7.25–8.09 (m, 5H, C_6H_5); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 50.2, 99.8, 122.2, 126.4, 129.3, 129.4, 132.2, 139.3, 141.8, 158.3, 159.3, 162.2; FT-IR (KBr): *ν*/cm^{-1} = 3233 (NH), 1657 (CO_2Me), 1598 (CO); MS (ESI): m/z = 269 (M^+).

4.1.5 Methyl 2-methyl-7-oxo-4,7-dihydropyrazolo[1,5-*a*]pyrimidine-5-carboxylate (3e)

Pale yellow solid; yield 0.095 g (92%); CC: yield 0.083 g (80%); m.p.: 186-187 °C; ^{1}H NMR (400 MHz, $CDCl_3$) *δ*: 2.07 (s, 3H, CH_3), 3.87 (s, 3H, OCH_3), 4.29 (s, 1H, NH), 6.21 (s, 1H, C_6-H), 6.69 (s, 1H, C_3-H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 14.8, 50.2, 89.80, 122.2, 141.8, 149.3, 158.3, 159.3, 162.2; FT-IR (KBr): *ν*/cm^{-1} = 3244 (NH), 1669 (CO_2Me), 1601 (CO); MS (ESI): m/z = 208 (MH^+).

4.2 Synthesis of the target 2 or/and 3-alkyl/aryl/cyano pyrazolo[1,5-*a*]pyrimidin-7(4*H*)-ones (3f-k)

For the preparation of pyrazolopyrimidine derivatives **3f-k**, the procedure described in Section 4.1 was followed, giving the products in 77–95% overall yields and after column the product were obtained in 63–85% yield. The spectral analytical data with the help of which, the structures of **3f-k** were established have been presented here under.

4.2.1 2-Phenylpyrazolo[1,5-*a*]pyrimidin-7(4*H*)-one (3f)

Pale brown solid; yield 0.081 g (77%); CC: yield 0.067 g (64%); m.p.: 133–134 °C; ^{1}H NMR (400 MHz, $CDCl_3$) *δ*: 4.26 (s, 1H, NH), 6.62 (s, 1H, C_3-H), 7.12 (d, 1H, *J* = 7.2 Hz, C_6-H), 7.24–8.46 (m, 5H, C_6H_5), 8.93 (d, 1H, *J* = 7.2 Hz, C_5-H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 90.4, 131.5, 131.6, 132.3, 133.5, 134.2, 147.6, 153.2, 155.7; FT-IR (KBr): *ν*/cm^{-1} = 3232 (NH), 1653 (CO); Anal. Calcd. for $C_{12}H_9N_3O$: C, 58.67; H, 3.28; Cl, 14.43; N, 17.10. Found: C, 58.51; H, 3.30; N, 17.07.

4.2.2 3-Phenylpyrazolo[1,5-*a*]pyrimidin-7(4*H*)-one (3g)

Pale brown solid; yield 0.83 g (79%); CC: yield 0.066 g (63%); m.p.: 163–164 °C; ^{1}H NMR (400 MHz, $CDCl_3$) *δ*: 4.14 (s, 1H, NH), 7.10 (d, 1H, J = 7.6 Hz, C_6-H), 7.73–8.20 (m, 5H, C_6H_5), 8.59 (s, 1H, C_2-H), 8.93 (d, 1H, *J* = 7.2 Hz, C_5-H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 109.2, 110.4, 131.5, 132.3, 133.0, 133.5, 135.0, 142.3, 147.6, 165.7; FT-IR (KBr): *ν*/cm^{-1} = 3242 (NH), 1667 (CO); Anal. Calcd. for $C1_2H_9N_3O$: C, 68.24; H, 4.29; N, 19.89. Found C, 68.02; H, 4.32; N, 19.82.

4.2.3 7-Oxo-4,7-dihydropyrazolo[1,5-*a*]pyrimidine-3-carbonitrile (3h)

Brown solid; yield 0.074 g (93%); CC: yield 0.068 g (85%); m.p.: 137–139 °C; ^{1}H NMR (400 MHz, $CDCl_3$) *δ*: 4.68 (s, 1H, NH), 6.99 (d, 1H, *J* = 6.8 Hz, C_6-H), 8.43 (d, 1H, *J* = 7.2 Hz, C_5-H), 8.59 (s, 1H, C_2-H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 79.5, 112.9, 117.2, 119.9, 143.5, 149.9, 159.2; FT-IR (KBr): *ν*/cm^{-1} = 3238 (NH), 1677 (CO); Anal. Calcd. for $C_7H_4N_4O$: C, 68.24; H, 4.29; N, 19.89. Found C, 68.34; H, 4.28; N, 19.85.

4.2.4 3-(4-Chlorophenyl)pyrazolo[1,5-*a*]pyrimidin-7(4*H*)-one (3i)

Pale brown solid; yield 0.104 g (85%); CC: yield 0.088 g (72%); m.p.: 142–144 °C; ^{1}H NMR (400 MHz, $CDCl_3$) *δ*: 4.51 (s, 1H, NH), 6.92 (d, 1H, *J* = 6.8 Hz, C_6-H), 7.17–7.91 (m, 4H, C_6H_5), 8.66 (s, 1H, C_2-H), 8.88 (d, 1H,

J = 7.2 Hz, C_5-H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 90.6, 110.4, 131.5, 132.3, 134.2, 135.0, 142.3, 145.5, 156.6, 157.8; FT-IR (KBr): ν/cm^{-1} = 3244 (NH), 1657 (CO); Anal. Calcd. for $C_{12}H_8ClN_3O$: C, 52.50; H, 2.52; N, 34.99. Found C, 52.59; H, 2.50; N, 34.69.

4.2.5 2-Methylpyrazolo[1,5-*a*]pyrimidin-7(4*H*)-one (3j)

Pale brown solid; yield 0.063 g (84%); CC: yield 0.084 g (73%); m.p.: 162–163 °C; ^{1}H NMR 400 MHz, $CDCl_3$) δ: 1.32 (s, 3H, CH_3), 4.16 (s, 1H, NH), 6.61 (s, 1H, C_3-H), 7.25 (d, 1H, J = 7.2 Hz, C_6-H), 8.63 (d, 1H, J = 7.2 Hz, C_5-H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 15.8, 71.2, 79.5, 140.1, 143.2, 149.9, 151.2; FT-IR (KBr): ν/cm^{-1} = 3243 (NH), 1677 (CO); Anal. Calcd. for $C_7H_7N_3O$: C, 56.37; H, 4.73; N, 28.17. Found C, 56.22; H, 4.75; N, 28.21.

4.2.6 Ethyl 7-oxo-4,7-dihydropyrazolo[1,5-*a*] pyrimidine-3-carboxylate (3k)

Pale brown solid; yield 0.098 g (95%); CC: yield 0.087 g (84%); m.p.: 145–146 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.43 (t, 3H, J = 6.8 Hz, CH_3), 4.46 (q, 2H, J = 6.8 Hz, CH_2), 4.77 (s, 1H, NH), 6.98 (d, 1H, J = 6.8 Hz, C_6-H), 8.29 (s, 1H, C_2-H), 8.75 (d, 1H, J = 6.8 Hz, C_5-H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 19.0, 27.3, 34.2, 34.9, 36.3, 63.7, 83.5, 157.6, 169.0; FT-IR (KBr): ν/cm^{-1} = 3243 (NH), 1644 (CO); Anal. Calcd. for $C_9H_9N_3O_3$: C, 52.17; H, 4.38; N, 20.28. Found C, 52.25; H, 4.37; N, 20.26.

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Conflict of interest

The authors declare no conflict of interest.

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