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GREEN SYNTHESIS OF PYRAZOLONE DERIVATIVES USING IONIC LIQUID AS AN EFFICIENT AND GREEN CATALYST VIA FACILE MULTI-COMPONENT REACTION PATH.

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Abstract :
A rapid and efficient protocol for the synthesis of pyrazolone derivatives has been developed from multi-component reaction of various 3-aryl-1-phenyl-1*H*-pyrazole-4-carboxaldehyde, ethyl acetoacetate and substituted phenyl hydrazine in the presence of green catalyst [HNMP][HSO_4]. These derivatives have been synthesized by three different method includes conventional reflux method, ultrasound, and microwave irradiation. The combination of ionic liquid as a green media with ultrasound and microwave irradiation makes the protocol environmentally benign. The major benefits of these green techniques are excellent yield at ambidient temperature, very short reaction time, simple work-up procedure and use of inexpensive catalyst.

Keywords:
3-aryl-1-phenyl-1*H*-pyrazole-4-carboxaldehyde, pyrazolone, multi-component strategy, ionic liquid, ultrasound irradiation, microwave irradiation etc.

Introduction:

Now a days ionic liquids (ILs) have incredible interest due to attractive alternatives to hazardous organic solvents as well as catalyst in various branches of synthetic chemistry. Moreover, ILs exhibits energetic physicochemical properties such as superior solvating capability, elevated polarity, excellent ionic conductivity, good electrical as well as thermal stability, large selectivity, low toxicity, non-flammability, non-volatility, vapor pressure and wide liquid range. Besides the acidic ionic liquids confirm the significant properties of excellent acidity, greater proton conductivity, excellent chemical stability **[1-10]**.
Multicomponent reactions (MCRs) are powerful approach for the synthesis of chemically and biological active heterocyclic compounds. This strategy have several unique compensation such as the formation of extremely diverse and complex molecules from readily available substrates in a single synthetic operation without isolation of intermediates, and with

maximum selectivity in minimal time, high atom economy, simplicity, synthetic efficiency. and high purity with good yields **[11-17]**.

Pyrazolone is a major scaffold in heterocyclic chemistry that occurs in various pharmaceutical drugs. It is a nonsteroidal anti-inflammatory agent used in the treatment of arthritis and other musculoskeletal and joint disorders. Pyrazolone and their derivatives also shows diverse activities like antibacterial, antiviral, analgesic, antipyretic, anti-inflammatory, antifungal, antidiabetic, hypoglycemic, antineoplastic activity and immunosuppressive agents etc. **[18-22]**. Their derivatives are of particular significance in pharmaceutical industry due to their numerous applications as antiphlogistic properties, uricosuric, treatment of brain ischemia and myocardial ischemia **[23-26]**. In recent era, a library of isoxazolone or pyrazolone derivatives were synthesized having androgen antagonists activity and some of them exhibited full antagonistic activity toward human prostate tumor LNCaP cells **[27-28]**.

In recent decades, a variety of methods have been investigated for the synthesis of 4-aryl methylenepyrazol-5(4*H*)-ones via two component condensation of pyrazolone and aldehydes in the presence of reaction promoters such as AcOH **[29],** borate zirconia **[30]**, catalyst free **[31]**, IL ethyl ammonium nitrate **[32]**, L-proline **[33]**, silica perchloric acid **[34]**, etc. under conventional reaction condition. Also limited work has been reported for the synthesis of 4-aryl methylenepyrazol-5(4*H*)-ones via multicomponent approach. For illustration of this, Ablajan K and et al. synthesized 4-aryl methylenepyrazol-5(4*H*)-ones by MCR under ultrasound condition.**[35]**

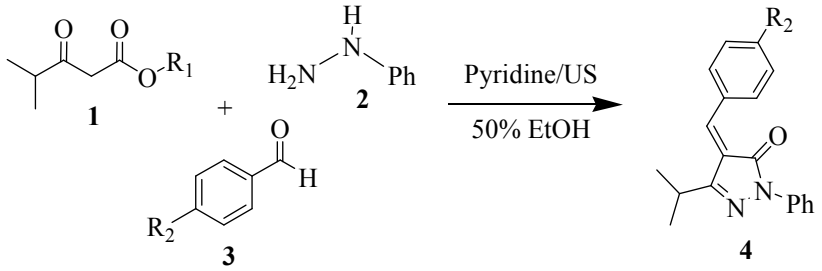


Figure I: Synthesis of 4-aryl methylenepyrazol-5(4*H*)-ones

In continuation of our work in the field of MCRs using ILs as a promoter **[36-40],** we have synthesized a series of pyrazolone derivatives from substituted 1,3-diphenyl-1*H*-pyrazole-4-carbaldehyde (**1**), ethyl acetoacetate (**2**), phenyl hydrazine (**3**) and a catalytic amount of *N*-Methyl-2-Pyrrolidonium Hydrogen Sulphate [HNMP][HSO_4] by the multi-component pathway. The 1,3-diaryl-1*H*-pyrazole-4-carbaldehyde were synthesized by Viels-meier Haack formylation reaction **[41-43].** They have received significant attention because of their broad spectrum of biological as well as pharmacological activities **[44-47].**

Results and Discussions:

Initially, we examined the model reaction between 1-phenyl-3-*p*-tolyl-1*H*-pyrazole-4-carbaldehyde **1a** (1 mmol), ethylacetoacetate **2** (1 mmol) and phenyl hydrazine **3** (1 mmol) in the presence of catalytic amount of [HNMP][HSO_4] under reflux condition. Additional experimentation revealed that, the yield of the desired product was increased with increasing the amount of catalyst from 50 to 100 mg (**Table 2**, Entries 4-6). The best results were obtained with 100 mg of catalyst [HNMP][HSO_4]. However the yield did not increase significantly with increasing amount up to 125 mg of catalyst (**Table 2**, Entry 7).

Table 1 Optimization of reaction condition to synthesize pyrazolone derivative (**4a**)

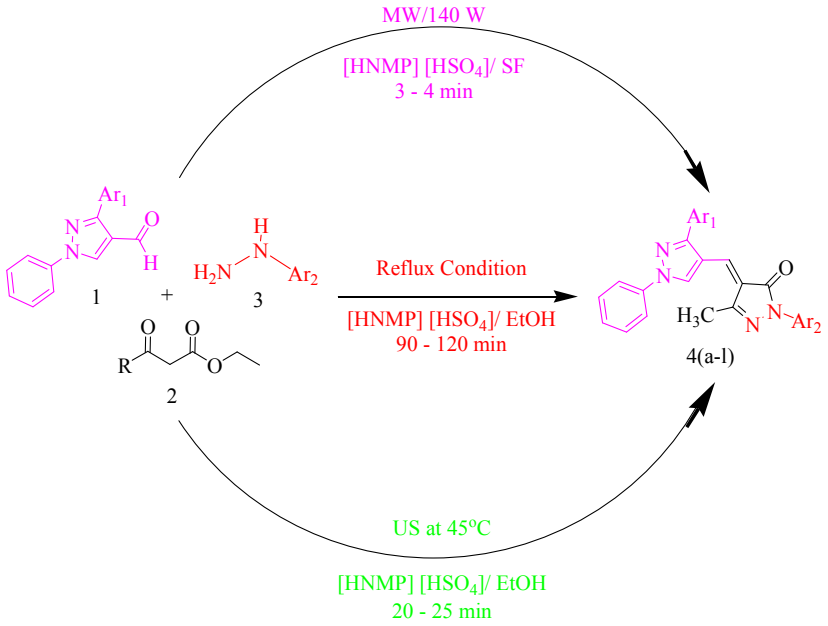
Entry	Catalyst/ Solvent	Reaction Condition	Time	Yield (%)
1	No catalyst/ Solvent free	Stirring at RT	5 h	NR
2	No catalyst/ Ethanol	Stirring at RT	5 h	NR
3	100 mg [HNMP] [HSO_4]/ SF	Stirring at RT	5 h	NR
4	50 mg [HNMP] [HSO_4]/ Ethanol	Reflux	2 h	30 %
5	75 mg [HNMP] [HSO_4]/ Ethanol	Reflux	2 h	72 %
6	100 mg [HNMP] [HSO_4]/ Ethanol	Reflux	2 h	86 %
7	125 mg [HNMP] [HSO_4]/ Ethanol	Reflux	2 h	87 %
8	100 mg [HNMP] [HSO_4]/ Ethanol	Ultrasound Irradiation at RT	20 min	Trace
9	100 mg [HNMP] [HSO_4]/ Ethanol	Ultrasound Irradiation at 45^{o}C	20 min	90 %
10	100 mg [HNMP] [HSO_4]/ SF	MW Irradiation at 140 W	3 min	92 %

Reaction Condition: 1-phenyl-3-*p*-tolyl-1*H*-pyrazole-4-carbaldehyde **1a** (1 mmol), Ethyl acetoacetate **2** (1 mmol), substituted phenyl hydrazine **3** (1 mmol) and 50-125 mg [HNMP][HSO_4]

When the model reaction was carried out under US irradiation, the reaction did not occur to any extent at room temperature. While good results appeared at 45˚C in short reaction time (**Table 2**, Entry 9). Also under MW condition, the better results are obtained at 140 W in solvent free condition (**Table 2**, Entry 10).

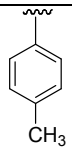
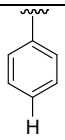
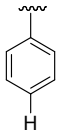
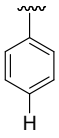
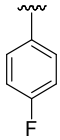
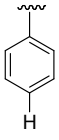
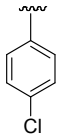
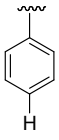
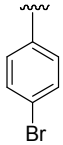
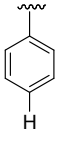
With the optimized reaction conditions in hand, the scope of the reaction was investigated by varying the substituents on heterocyclic aldehyde and phenyl hydrazine. The heterocyclic aldehyde with both electron-donating and electron-withdrawing substituents were tolerated, affording the desired product in high yield (**Table 1,** Entries **4a-h**) under reflux, ultrasound and microwave conditions. Also good results were obtained with fluorinated phenyl hydrazine (**Table 1,** Entries **4i-l**). All the conventional and non-conventional methods provided good results with IL. However, the Microwave and Ultrasound methods provided good yield in a short period of time.

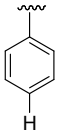
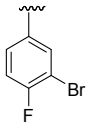
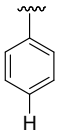
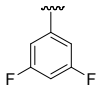
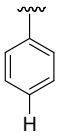
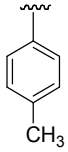
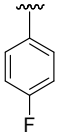
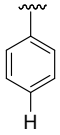
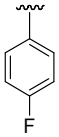
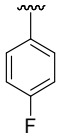
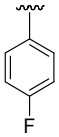
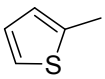
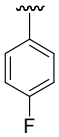
Scheme-



Scheme I. Synthesis of Pyrazolone derivatives

Table 2 Synthesis of pyrazolone derivatives (**4a-l)** using [HNMP] [HSO_4] as a catalyst

Entry	Ar_1 Group	Ar_2 Group	Reaction Time in Min.			Yield in %			M.P. in (^oC)
			Reflux	US	MW SF	Reflux	US	MW SF	
4a			100	20	4	75	84	86	218
4b			100	20	3	78	80	86	236
4c			110	20	4	70	78	82	238
4d			120	25	4	72	78	80	240
4e			120	25	4	74	80	84	216

4f			90	20	3	76	84	86	220
4g			90	25	4	72	78	84	202
4h			110	25	4	70	80	82	208
4i			120	20	3	72	82	84	240
4j			100	20	3	76	84	86	258
4k			120	25	4	74	82	88	270
4l			110	25	3	78	84	88	228

Reaction Condition: 3-aryl-1-phenyl-1*H*-pyrazole-4-carbaldehyde **1** (1 mmol), Ethyl acetoacetate **2** (1 mmol), substituted phenyl hydrazine **3** (1 mmol), 100 mg [HNMP] [HSO_4] and 10 mL ethanol.

Experimental:

General: Melting points were recorded in an open capillary and are uncorrected. IR spectra were recorded on a Perkin-Elmer FTIR spectrophotometer. The ^{1}H NMR spectrums were recorded on a Brucker Avance II 400MHz in $CDCl_3$ using TMS as an internal standard compound. Mass spectra were recorded on a Finnigan Mass spectrometer with specification LC-MS Spectrometer. TLC was carried out on pre-coated silica gel Al- plates to check the purity of the compounds.

Preparation of N-Methyl-2-Pyrrolidonium Hydrogen Sulphate [HNMP][HSO_4]

The 250 mL round bottom flask was placed in an ice bath which was filled with N-methylpyrrolidone (19.8 mL, 0.2 mol). Then concentrated sulphuric acid (19.6 mL, 0.2 mol) was added drop wise with constant stirring to the flask within 40-50 min. Then the reaction flask was heated for 15 h at 80^{o}C to complete the reaction. The resultant mixture was washed more than two times with diethyl ether to remove non-ionic matter. Then ionic liquid and the ether layer were separated by the separating funnel. Finally dry it well in a rotary evaporator for 6 h to obtain the viscous liquid [HNMP][HSO_4].

General Procedure for the Synthesis of Pyrazolinone Derivatives

a. under conventional reflux condition

A mixture of 3-aryl-1-phenyl-1*H*-pyrazole-4-carboxaldehyde **1** (1 mmol), ethyl acetoacetate **2** (1 mmol), substituted phenyl hydrazine **3** (1 mmol) and 100 mg of ionic liquid [HNMP][HSO_4] was taken in a 100 mL round bottom flask containing 10 mL of ethanol. Then the reaction mixture was refluxed for appropriate time. The progress of the reaction was monitored by TLC. After completion of the reaction, the content were cooled to room temperature, solid product thus obtained was separated by filtration. The crude product was washed with cold ethanol to get pure product.

b. under US irradiation

A mixture of 3-aryl-1-phenyl-1*H*-pyrazole-4-carboxaldehyde **1** (1 mmol), ethyl acetoacetate **2** (1 mmol), substituted phenyl hydrazine **3** (1 mmol) and 100 mg of ionic liquid [HNMP][HSO_4] was taken in a 100 mL round bottom flask containing 10 mL of ethanol. The reaction mixture was placed for US irradiation at 45^oC for appropriate time. The progress of the reaction was monitored by TLC. After completion of the reaction, the content were cooled to room temperature, solid product thus obtained was separated by filtration. The crude product was washed with cold ethanol to get pure product.

c. under MW irradiation

A mixture of 3-aryl-1-phenyl-1*H*-pyrazole-4-carboxaldehyde **1** (1 mmol), ethyl acetoacetate **2** (1 mmol), substituted phenyl hydrazine **3** (1 mmol) and 100 mg of ionic liquid [HNMP][HSO_4] was taken in a 100 mL round bottom flask containing 10 mL of ethanol. The reaction mixture was subjected for MW irradiation at level 1 (140 W) for appropriate time. The progress of the reaction was monitored by TLC. After completion of the reaction, the content were cooled to room temperature, solid product thus obtained was separated by filtration. The crude product was washed with cold ethanol to get pure product.

Spectral Data-

4a: 3-methyl-1-phenyl-4-((1-phenyl-3-*p*-tolyl-1*H*-pyrazol-4-yl)methylene)-1*H*-pyrazol-5(4*H*)-one - Yellow Solid; M.P. 218˚C; FT-IR (KBr) ν: 3145, 2981, 1672, 1608, 1595, 1530, 1498, 1366, 1317, 1216, 1151, 998, 749; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.11 (s, 3H, -CH_3), 2.83 (s, 3H, -CH_3), 7.19 (d, J=7.3 Hz, 1H, Ar-H), 7.39-7.47 (m, 5H, Ar-H), 7.58-7.63 (m, J=7.6 and 7.3 Hz, 4H, Ar-H), 7.93 (d, J=7.9 Hz, 2H, Ar-H), 7.99 (d, J=7.6 Hz, 2H, Ar-H), 8.15 (s, 1H, Pyrazole ring-H), 10.24 (s, 1H, vinylic proton); MS: m/z= 419.37[M+1]$^+$.

4b: 3-methyl-1-phenyl-4-((1,3-diphenyl-1*H*-pyrazol-4-yl)methylene)-1*H*-pyrazol-5(4*H*)-one

Yellow Solid; M.P. 236˚C; FT-IR (KBr) ν: 3143, 3048, 2981, 1669, 1612, 1596, 1520, 1497, 1322, 1217, 1147, 999, 820, 748; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.14 (s, 3H, -CH_3), 7.29 (t, 2H, Ar-H), 7.44 (t, 2H, Ar-H), 7.54-7.62 (m, 6H, Ar-H), 7.76 (d, 2H, Ar-H), 7.92-7.98 (m, 4H, Ar-H and Pyrazole ring-H), 10.18 (s, 1H, vinylic proton); MS: m/z= 405.36[M+1]$^+$

4c: 4-((3-(4-fluorophenyl)-1-phenyl-1*H*-pyrazol-4-yl)methylene)-3-methyl-1-phenyl-1*H*-pyrazol-5(4*H*)-one -Yellow Solid; M.P. 238˚C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.31 (s, 3H, -CH_3), 7.31 (t, 3H, Ar-H), 7.42-7.49 (m, 2H, Ar-H), 7.59 (s, 1H, Ar-H), 7.64 (t, 2H, Ar-H), 7.84 (d, 2H, Ar-H), 7.94-7.98 (m, 5H, Ar-H and Pyrazole ring-H), 10.24 (s, 1H, vinylic proton); MS: m/z= 423.13[M+1]$^+$.

4d: 4-((3-(4-chlorophenyl)-1-phenyl-1*H*-pyrazol-4-yl)methylene)-3-methyl-1-phenyl-1*H*-pyrazol-5(4*H*)-one: Yellow Solid; M.P. 240˚C; FT-IR (KBr) ν: 3144, 3054, 2882, 1673, 1611, 1593, 1568, 1442, 1367, 1213, 1216, 1151, 999, 833, 749; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.30 (s, 3H, -CH_3), 7.37 (t, 1H, Ar-H), 7.46-7.56 (m, 3H, Ar-H), 7.61 (s, 1H, Ar-H),

7.62-7.82 (m, 4H, Ar-H), 7.84 (d, 2H, Ar-H), 7.92-8.01 (m, 4H, Ar-H and Pyrazole ring-H), 10.21 (s, 1H, vinylic-H); MS: m/z= 439.15 $[M+1]^+$.

4e: 4-((3-(4-bromophenyl)-1-phenyl-1*H*-pyrazol-4-yl)methylene)-3-methyl-1-phenyl-1*H*-pyrazol-5(4*H*)-one -Yellow Solid; M.P. 216˚C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.28 (s, 3H, -CH_3), 7.24 (t, 1H, Ar-H), 7.45-7.52 (m, 3H, Ar-H), 7.56 (s, 1H, Ar-H), 7.65 (m, 2H, Ar-H), 7.76-7.78 (m, 2H, Ar-H), 7.81-7.83 (m 2H, Ar-H), 7.95-7.98 (m, 4H, Ar-H and Pyrazole ring-H), 10.20 (s, 1H, vinylic-H); MS: m/z= 483.17 $[M+1]^+$.

4f: 3-methyl-1-phenyl-4-((1-phenyl-3-(thiophen-2-yl)-1*H*-pyrazol-4-yl)methylene)-1*H*-pyrazol-5(4*H*)-one -Yellow Solid; M.P. 220˚C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.36 (s, 3H, -CH_3), 7.29-7.35 (m, 3H, Ar-H), 7.51 (t, J=6.4 Hz, 1H, Ar-H), 7.63 (t, J=6.4 Hz, 2H, Ar-H), 7.78 (d, 2H, Ar-H), 7.80 (s, 1H, Pyrazole ring-H), 7.86 (dd, 1H, Ar-H), 7.91 (dd, 2H, Ar-H), 7.99 (m, 2H, Ar-H), 10.23 (s, 1H, vinylic-H); MS: m/z= 411.22 $[M+1]^+$.

4g: 4-((3-(3-bromo-4-fluorophenyl)-1-phenyl-1*H*-pyrazol-4-yl)methylene)-3-methyl-1-phenyl-1*H*-pyrazol-5(4*H*)-one -Yellow Solid; M.P. 202˚C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.30 (s, 3H, -CH_3), 7.22 (t, 1H, Ar-H), 7.32 (m, 2H, Ar-H), 7.40 (m, 2H, Ar-H), 7.47 (m, 3H, Ar-H), 7.79 (m, 2H, Ar-H), 7.87 (d, 2H, Ar-H), 7.98 (m, 1H, Ar-H), 8.01 (s, 1H, Pyrazole ring-H), 10.21 (s, 1H, vinylic-H); MS: m/z= 501.10 $[M+1]^+$.

4h: 4-((3-(3,5-difluorophenyl)-1-phenyl-1*H*-pyrazol-4-yl)methylene)-3-methyl-1-phenyl-1*H*-pyrazol-5(4*H*)-one -Yellow Solid; M.P. 208˚C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.34 (s, 3H, -CH_3), 7.36 (t, 3H, Ar-H), 7.49 (t, 3H, Ar-H), 7.62 (m, 2H, Ar-H), 7.77 (d, 2H, Ar-H), 7.88 (s, 1H, Pyrazole ring-H), 7.99 (m, 2H, Ar-H), 8.02 (dd, 1H, Ar-H), 10.22 (s, 1H, vinylic-H); MS: m/z= 441.22 $[M+1]^+$.

4i: 1-(4-fluorophenyl)-3-methyl-4-((1-phenyl-3-*p*-tolyl-1*H*-pyrazol-4-yl)methylene)-1*H*-pyrazol-5(4*H*)-one - Yellow Solid; M.P. 240˚C; FT-IR (KBr) ν: 3139, 3054, 2980, 1674, 1594, 1498, 1219, 1149, 748; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.01 (s, 3H, -CH_3), 2.28 (s, 3H, -CH_3), 7.26 (m, J=7.3 Hz, 2H, Ar-H), 7.41 (t, 2H, Ar-H), 7.46 (t, 1H, Ar-H), 7.56-7.67 (m, 4H, Ar-H), 7.94 (t, 2H, Ar-H), 7.97-8.01 (m, 2H, Ar-H), 8.26 (s, 1H, Pyrazole ring-H), 10.22 (s, 1H, vinylic proton); MS: m/z= 437.35$[M+1]^+$.

4j:1-(4-fluorophenyl)-3-methyl-4-((1,3-diphenyl-1*H*-pyrazol-4-yl)methylene)-1*H*-pyrazol-5(4*H*)-one -Yellow Solid; M.P. 258˚C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.29 (s, 3H, -CH_3), 7.31 (t, 2H, Ar-H), 7.50 (t, 2H, Ar-H), 7.59-7.66 (m, 5H, Ar-H), 7.81 (dd, 2H, Ar-H), 7.95-8.00 (m, 4H, Ar-H and Pyrazole ring-H), 10.22 (s, 1H, vinylic-H); MS: m/z= 423.23$[M+1]^+$.

4k: 1-(4-fluorophenyl)-4-((3-(4-fluorophenyl)-1-phenyl-1*H*-pyrazol-4-yl)methylene)-3-methyl-1*H*-pyrazol-5(4*H*)-one -Yellow Solid; M.P. 270˚C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.29 (s, 3H, -CH_3), 7.30 (t, J=5.2 and 2.0 Hz, 2H, Ar-H), 7.44-7.50 (m, J=7.2, 5.2 and 2.8 Hz, 2H, Ar-H), 7.56 (s, 1H, Ar-H), 7.65 (t, J=6.8 and 6.0 Hz, 2H, Ar-H), 7.85-7.88 (m, 2H, Ar-H), 7.93-7.99 (m, 5H, Ar-H and Pyrazole ring-H), 10.21 (s, 1H, vinylic-H); MS: m/z= 441.16$[M+1]^+$.

4l: 1-(4-fluorophenyl)-3-methyl-4-((1-phenyl-3-(thiophen-2-yl)-1*H*-pyrazol-4-yl)methylene)-1*H*-pyrazol-5(4*H*)-one - Yellow Solid; M.P. 228˚C; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.37 (s, 3H, -CH_3), 7.30-7.34 (m, 3H, Ar-H), 7.50 (t, J=6.0 Hz, 1H, Ar-H), 7.63 (t, J=6.0 Hz, 2H, Ar-H), 7.75 (dd, 1H, Ar-H), 7.79 (s, 1H, Pyrazole ring-H), 7.84 (dd, 1H, Ar-H), 7.92 (dd, 2H, Ar-H), 7.98 (m, 2H, Ar-H), 10.19 (s, 1H, vinylic-H); MS: m/z= 429.24$[M+1]^+$.

Abbreviations: MCRs= Multi-component reaction, NR= No Reaction, ILs= Ionic liquids, RT= Room Temperature, [HNMP][HSO_4]= *N*-Methyl-2-Pyrrolidonium Hydrogen Sulphate, US= Ultrasound, MW= Microwave.

Conclusion:

We have developed a new method for the one-pot synthesis of pyrazolinone derivatives using ionic liquid [HNMP][HSO_4] as an efficient catalyst. A library of pyrazolinone **4(a-l)** derivatives was synthesized from 3-aryl-1-phenyl-1*H*-pyrazole-4-carbaldehyde, ethyl acetoacetate and substituted phenyl hydrazine in ethanol by conventional reflux condition, US and MW irradiation for suitable time. The advantage of US and MW assisted reaction in [HNMP][HSO_4] are of short reaction time, mild reaction condition, and high yield.

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References

i. D.A. Hilal and H.D. Hanoon, Res. Chem. Intermed. 46, 1521 (2020).
ii. J. Ranke, S. Stolte, R. Stormann, J. Arning and B. Jastorff, Chem. Rev. 107, 2183 (2007).
iii. R.D. Padmaja and K. Chanda, Res. Chem. Intermed. 46, 1307 (2020).
iv. J. Nowicki, M. Muszynski and S. Gryglewicz, Chem. Technol. Biotechnol. 89, 48 (2014).
v. T. Welton, Coord. Chem. Rev. 248, 2459 (2004).
vi. P. Wasserscheid and W. Keim, Angew. Chem. Int. Ed. 39, 3772 (2000).
vii. J. Dupont, R.F. Souza and P.A.Z. Suarez, Chem. Rev. 102, 3667 (2002).
viii. S. Steudte, S. Bemowsky, M. Mahrova, U. Bottin-Weber, E. Tojo-Suarez, P. Stepnowski and S. Stolte, RSC Adv. 4, 5198 (2014).
ix. A.N. Masri, M.A. Mutalib, N.F. Aminuddin and J.M. Leveque, Sep. Purif. Technol. 196, 106 (2018).
x. J.S. Wilkes, Green Chem. 4, 73 (2002).
xi. K. Khan and Z. Siddiqui, Ind. Eng. Chem. Res. 54, 6611 (2015).
xii. B.H. Rotstein, S. Zaretsky, V. Rai and A.K. Yudin, Chem. Rev. 114, 8323 (2014).
xiii. P. Kumara, K. Hussainb and A. Kumar, Curr. Chem. Lett. 3, 75 (2014).
xiv. S. Maddila, S. Maddila, W. Zyl and S. Jonnalagadda, Res. Chem. Intermed. 42, 2553 (2016).
xv. A. Domling, W. Wang and K. Wang, Chem. Rev. 112, 3083 (2012).
xvi. L. Saher, M. Chebli, L. Dermeche, B. Khedis, C. Rabia, A. Silva and M. Hamdi, Tetrahedron Lett. 57, 1492 (2016).
xvii. A. Saha, S. Payra and S. Banerjee, Green Chem. 17, 2859 (2015).
xviii. A. Gursoy, S. Demirayak, G. Capan, K. Erol and K. Vural, Eur. J. Med. Chem. 35, 359 (2000).
xix. A.A. Bekhit, H. M. Ashous and A.A. Guemei, Arch. Pharm. 338, 167 (2005).
xx. N. Parekh, K. Maheria, P. Patel P and M. Rathod, Int. J. Pharm. Tech. Res. 3, 540 (2011).
xxi. R.V. Ragavan, V. Vijayakumar and N. S. Kumari, Eur. J. Med. Chem. 44, 3852 (2009).
xxii. R.V. Antre, A. Cendilkumar, D. Goli, G.S. Andhale and R.J. Oswal, Saudi Pharm. J. 19, 233 (2011).
xxiii. H. Kawai, H. Nakai, M. Suga, S. Yuki, T. Watanabe and K.I. Saito, J. Pharmacol. Exp. Ther. 281, 921 (1997).
xxiv. T. Ueda, H. Mase, N. Oda and I. Ito, Chem. Pharm. Bull. 29, 3522 (1981).

xxv. J. Hukki, P. Laitinen P and J.E. Alberty, Pharma. Acta. Helvet. 43, 704 (1968).
xxvi. T.W. Wu, L.H. Zeng, J. Wu and K.P. Fung, Life Sci. 71, 2249 (2002).
xxvii. T. Ishioka, A. Tanatani, K. Nagasawa and Y. Hashimoto, Bioorg. Med. Chem. 13, 2655 (2003).
xxviii. T. Ishioka, A. Kubo, Y. Koiso, K. Nagasawa, A. Itai and Y. Hashimoto, Bioorg. Med. Chem. 10, 1555 (2002).
xxix. S.N. Shelke, N.R. Dalvi, S.B. Kale, M.S. More, C.H. Gill and B.K. Karale, Indian J. Chem. 46B, 1174 (2007).
xxx. S.S. Shindalkar, B.R. Madje, R.V. Hangarge, T. P. Pratap, K.D. Mohan and S.S. Murlidhar, J. Korean Chem. Soc. 49, 377 (2005).
xxxi. S.S. Gholap, Heterocycl Lett. 2, 461 (2012).
xxxii. V. H. Rajkumar and S.S. Murlidhar, Mendeleev Commun, 2, 79 (2003).
xxxiii. K.V. Swamy and P.K. Dubey, Org. Chem.: An Indian J. 11, 392 (2015).
xxxiv. B.R. Madje, S.S.Shindalkar, M.N.Ware and M.S. Shingare, ARKIVOC. (xiv), 82 (2005).
xxxv. K. Ablajan and H. Xiamuxi, Synth. Commun. 42, 1128 (2012).
xxxvi. G. Shirole, V. Kadnor, A. Tambe and S. Shelke, Res. Chem. Intermed. 43, 1089 (2017).
xxxvii. G. Shirole and S. Shelke, Lett. Org. Chem. 13, 742 (2016).
xxxviii. G. D. Shirole, R. A. Mokal and S. N. Shelke, Lett. Org. Chem. 14, 548 (2017).
xxxix. G. D. Shirole, A. G. Gadhave, S. Bhalekar and S. N. Shelke, Indian J. Heterocycl. Chem. 27, 195 (2017).
xl. G. D. Shirole, S. B. Bhalekar and S. N. Shelke, Indian J. Chem. Sec. B 57B, 1430 (2018).
xli. V.A. Chornous and M.K. Bratenko, Chemistry of Heterocyclic Compounds, New York, United States, Springer Sci. 42, 1242 (2006).
xlii. O. Prakash, K. Pannu, R. Naithani and H. Kaur, Synth. Commun. 36, 3479 (2006).
xliii. M.N. Jachak, A.B. Avhale, C.D. Tantak and R.B. Toche, J. Heterocycl. Chem. 42, 1311 (2005).
xliv. S.N. Shelke, G.R. Mhaske, V.D.B. Bonifacio and M.B. Gawande, Bioorg. Med. Chem. Lett. 22, 5727 (2012).
xlv. S. Viveka, R. Dinesha, P. Sharma, S. Naveen, N. Lokanath and G.K. Nagaraja, RSC Adv. 5, 94786 (2015).
xlvi. B.F. Abdel-Wahab, R.E. Khidre and A.A. Farahat, ARKIVOC. (i), 196 (2011).
xlvii. M.J. Naim, O. Alam, F. Nawaz, M.J. Alam and P. Alam, J. Pharm. Bioallied Sci. 8, 2 (2016).

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