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Phase-transfer catalyzed acylation of 5(3)-hydroxy-3(5)-substituted-1H-pyrazoles

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PTC acylation of 5(3)-hydroxy-3(5)-substituted-1*H*-pyrazoles by different acyl halide reagents at 25°C in the presence of tetrabutylammonium bromide as catalyst has been investigated. This work is aiming to study the comparison of N-*versus* O- and C-acylation of the starting materials.

Keywords: Phase-transfer catalysis (PTC), acylation, heterogeneous reactions, 1*H*-pyrazoles, tetrabutylammonium bromide (TBAB), solid/liquid phases

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Phase-transfer catalysis (PTC) is one of the promising methods in organic synthesis of specialty chemicals.

In the last 20 years, a steadily increasing number of published papers and patents dealing with phase transfer catalysis and its applications. PTC is not merely important for substitution reactions but, nowadays, it is being extensively applied in polymer chemistry, heterocyclic chemistry, organometallic chemistry, agrochemicals, dyes, flavors, perfumes and pharmaceuticals manufacture[1-3].

The technique of PTC has, extensively, been applied in the organic synthesis via substitution, displacement, condensation, elimination, redox, polymerization and Ylide-mediated reactions. The most advantages of using PTC technique to synthesize organic chemicals are the enhancement of the reaction rate, carrying out the reaction at moderate conditions, obtaining high selectivity of the main product with high conversion of the reactants[4,5].

5-Pyrazolones are very important class of heterocycles due to their biological and pharmacological activities[6,7], which exhibit anti-inflammatory[8], herbicidal[9], fungicidal[10], bactericidal[10], plant growth regulating properties[9], antipyretic properties[11] and act as protein kinase inhibitors[12].

Also, they are used as key starting for the synthesis of commercial arylazopyrazolone dyes. Acyl-5-pyrazolones are a family of heterocyclic proligands and coordinated with some metal ions in anionic O_2-chelating mode[13,14].

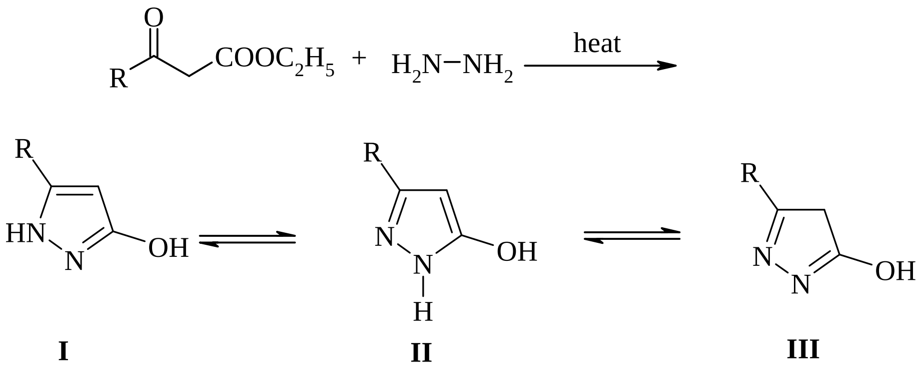
Results and Discussion

The approach reported here is an extension and continuation of our interest of heterocycles reactions under phase-transfer catalysis (PTC) conditions[15-21]. This work is aimed at studying the phase-transfer catalyzed acylation of 5(3)-hydroxy-3(5)-substituted-1*H*-pyrazoles and the comparative reactivity towards N-*versus* O-*versus* C-acylation upon treatment with different acid halide reagents in liquid/solid phases and in the presence of tetrabutylammonium bromide (TBAB) as a catalyst at 25°C.

5(3)-Hydroxy-3(5)-substituted-1*H*-pyrazoles **1a-c** have been synthesized by heating a mixture of β-ketoesters with hydrazine hydrate. They are existed in three, predominant, tautomeric forms **I-III** due to their keto-enol or lactam-lactime tatoumerism, **Scheme I**.

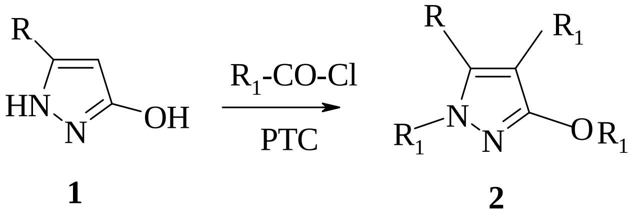
The full aromatic enol forms **I** and **II** are the predominate which is confirmed by spectral data and X-ray analysis of our recent reported results[22] of PTC-acylation of 5-hydroxy-3-substitued-1*H*-pyrazoles which are afforded C_5-O- and N_1-diacylated products.

After deep experimental studies of PTC-acylation of pyrazoles **1a-c** by changing the phases, organic solvent, reactants molarity, catalyst and reaction temperature, it was found that the optimized reaction conditions of our PTC-acylation are the treatment of pyrazoles **1a-c** with different acid chlorides in a 1:3 molar ratio, respectively in acetonitrile or dioxane as a



1: a, R = CH_3; **b**, R = C_6H_5; **c**, R= pyrid-3-yl

Scheme I



Scheme II

liquid phase and anhydrous potassium carbonate as a basic solid phase and in the presence of tetrabutylammonium bromide (TBAB) as a catalyst at 25°C with vigorous and efficient stirring for a limited short time where the reaction progress was monitored by TLC.

Acylation of 5(3)-Hydroxy-3(5)-substituted-1*H*-pyrazoles **1a-c** under the optimized PTC reaction conditions in solid/liquid phases by different acyl chlorides proved their existence in lactim form **1**, **Scheme II**.

Acetylation of 3-hydroxy-5-methyl-1*H*-pyrazoles **1a-c** under the optimized PTC reaction conditions in solid/liquid phases by acetyl chloride underwent and O-acetylation, only, to give 5-methyl-1*H*-pyrazole-3-yl acetate **2**. Wherever, 3-hydroxy-5-phenyl-1*H*-pyrazole **1b** was triacetylated under the same PTC-conditions to give 1,4-diacetyl-5-phenyl-1*H*-pyrazol-3-yl acetate **3** *via* N_1-, C_4- and O-triacetylation, **Scheme II**, **Table I**.

Benzoylation of 3-hydroxy-5-methyl-1*H*-prazole **1a** in the solid/liquid optimized PTC conditions yielded two products, 1-benzoyl-5-methyl-1*H*-pyrazol-3-yl benzoate **4** *via* N_1- and O-dibenzoylation and 1,4-dibenzoyl-5-methyl-1H-pyrazol-3-yl benzoate **5** *via* N_1-, C_4- and O-tribenzoylation. The dibenzoylated product **4** has been recovered from the organic layer, while the tribenzoylated product **5** was isolated after acidification of the K_2CO_3 solution, **Scheme II**, **Table I**.

However, benzoylation of 3-hydroxy-5-phenyl-1*H*-pyrazole **1b** under the same optimized PTC conditions underwent O-benzoylation, only to give 5-phenyl-1*H*-pyrazol-3-yl benzoate **6**, while 3-hydroxy-5-(pyrid-3-yl)-1*H*-pyrazole **1c** yielded only the tribenzoylated product, 1,4-dibenzoyl-5-(pyrid-3-yl)-1*H*-pyrazol-5-yl- benzoate **7**, **Scheme II**, **Table I**.

Acylation of 3-hydroxy-5-methyl-1*H*-pyrazole **1a** by *p*-toulyl chloride, *p*-anisoyl chloride or cinnamoyl chloride in dioxane/K_2CO_3 as liquid/solid phases and in the presence of TBAB as a catalyst at 25°C underwent N_1- and O-acylation to give 1-(4-methylbenzoyl)-5-methyl-1*H*-pyrazol-3-yl(4-methyl)benzoate,1-(4-methoxybenzoyl) 5-methyl-1*H*-pyrazol-3-yl (4-methoxy)benzoate and 1-cinnamoyl-5-methyl-1*H*-pyrazol-3-yl cinnamate **8-10,** respectively, **Scheme II**, **Table I**.

However, 3-hydroxy-5-phenyl-1*H*-pyrazole **1b** was acylated by *p*-toluoyl chloride, *p*-anisoyl chloride or cinnamoyl chloride under the same PTC conditions to give O-acylated product, only, to give 5-phenyl-1*H*-pyrazol-3-yl (4-methyl)benzoate, 3-phenyl-1*H*-pyrazol-5-yl(4-methoxy)benzoate and 5-phenyl-1*H*-pyrazol-3-yl cinnamate **11-13**, respectively, **Scheme II**, **Table I**.

Treatment of 3-hydroxy-5-substituted-1*H*-pyrazoles **1a-c** with 4-chloro-benzoyl chloride (1:3) in acetonitrile/K_2CO_3 as liquid/solid phases and in the presence of TBAB as catalyst at 25°C underwent simultaneous N_1- and O-diacylation to give 5-substituted-1-(4-chlorobenzoyl)-1*H*-pyrazol-3-yl (4-chloro) benzoate **14-16**, respectively, **Scheme II**, **Table I**.

Table I — Acylated products of 3-hydroxy-5-substituted-1*H*-pyrazoles **1a-c**

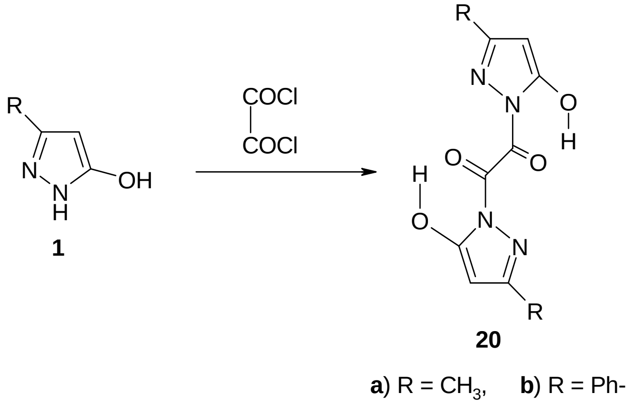
Compd	C_5-R	N_1-R_1	O-R_1	C_4-R_1
2	CH_3	H	$COCH_3$	H
3	C_6H_5	$COCH_3$	$COCH_3$	$COCH_3$
4	CH_3	COPh	COPh	H
5	CH_3	COPh	COPh	COPh
6	C_6H_5	H	COPh	H
7	C_5H_4N,3-	COPh	COPh	COPh
8	CH_3	COC_6H_4, CH_3, 4-	COC_6H_4, CH_3, 4-	H
9	CH_3	COC_6H_4, OCH_3, 4-	COC_6H_4, OCH_3, 4-	H
10	CH_3	$COCH{=}CHC_6H_5$	$COCH{=}CHC_6H_5$	H
11	C_6H_5	H	COC_6H_4, CH_3, 4-	H
12	C_6H_5	H	COC_6H_4, OCH_3, 4-	H
13	C_6H_5	H	$COCH{=}CHC_6H_5$	H
14	CH_3	COC_6H_4, Cl, 4-	COC_6H_4, Cl, 4-	H
15	C_6H_5	COC_6H_4, Cl, 4-	COC_6H_4, Cl, 4-	H
16	C_5H_4N,3-	COC_6H_4, Cl, 4-	COC_6H_4, Cl, 4-	H
17	CH_3	H	$SO_2C_6H_4$, CH_3, 4-	H
18	C_6H_5	H	$SO_2C_6H_4$, CH_3, 4-	H
19	C_5H_4N,3-	H	$SO_2C_6H_4$, CH_3, 4-	H

PTC-tosylation of 3-hydroxy-5-substituted-1*H*-pyrazoles **1a-c** by toluene-4-sulphonylchloride in acetonitrile/K_2CO_3 as liquid/solid phases and TBAB as catalyst at 25°C, afforded the O-tosylation, only, to give 5-substituted-1*H*-pyrazol-5-yl tosylate **17-19**. The pure product was separated from the crude oily products by column chromatography using petroleum ether 60-80, ethyl acetate (2:3) for 5-methyl-1*H*-pyrazol-3-yl tosylate **17**; petroleum ether 60-80, ethyl acetate, chloroform (6:4:1) for 5-phenyl-1*H*-pyrazol-3-yl tosylate **18**; and petroleum ether 80-100, ethyl acetate (1:4) for 5-(pyrid-3-yl)-1*H*-pyrazol-3-yl tosylate **19, Scheme II Table I**.

PTC-Acylation by oxalyl chloride of **1a, b** in tautomeric form **II**, 5-hydroxy-3-substituted-1*H*-pyrazole in 1:1 molar ratio in dioxane/anhydrous K_2CO_3 as liquid/solid phases, in the presence of TBAB as a catalyst at room temperature yielded 1,2-bis[(5-hydroxy-3-substituted)-l*H*-pyrazol-1-yl)]ethane-1,2-dione **20 a, b, Scheme III**.

Experimental Section

All melting points reported are uncorrected. IR spectra were recorded using Perkin-Elmer's spectrum RXIFT-IR spectrophotometer (ν in cm^{-1}). The NMR spectra were recorded on Bruker-Avance DPX400 spectrometer, using $CDCl_3$ as solvent and TMS as internal standard (chemical shifts in δ values in ppm. Elemental analyses were performed on Perkin-Elmer 2400 series II microanalyzer.



Scheme III

Condensation of β-ketoester with hydrazine hydrate synthesis of 5-hydroxy-3-substituted-1*H*-pyrazoles 1a-c. A solution of ethyl acetoacetate, (0.01 mole, 1.54 g), ethyl benzoylacetate (0.01 mole, 1.92 mL) or ethyl nicotinoylacetate (0.01 mole, 1.94 g) and hydrazine hydrate (100%, 0.01 mole, 0.48 g) in ethanol (50 mL) was refluxed for 6 hr followed by evaporation of the solvent. The solid residue was crystallized from ethanol to give the corresponding pyrazole **1a, b, c,** respectively as colorless crystals. The m.p.'s and yields are listed in **Table II** and spectroscopic details, are depicted in **Table III**.

General Procedure of PTC-acylation: In a 150 mL conical flask, fitted with a rubber stopper, a suspension of 5-hydroxy-3-substituted-1*H*-pyrazoles

Table II — The Physical data of acylated products compounds **1-20**

Compd	Reaction period t (in hr)	Mol. Formula (Mol. Wt.)	m.p. °C (colour)	Cryst Solvent* Yield (%)	Elemental analysis Calcd (Found) %		
					C	H	N
1a	—	$C_4H_6N_2O$	218-20	E	48.97	6.16	28.55
		(98.10)		(60)	(48.72	6.03	28.41)
1b	—	$C_9H_8N_2O$	238-40	E	67.49	5.03	17.49
		(160.18)		(65)	(67.31	4.96	17.33)
1c	—	$C_8H_7N_3O$	260-61	E	59.62	4.38	26.07
		(161.16)		(55)	(59.44	4.32	25.92)
2	0.25	$C_6H_8N_2O_2$	125-26	E	51.42	5.75	19.99
		(140.24)	(colourless)	55	(51.27	5.68	19.72)
3	4	$C_{15}H_{14}N_2O_4$	129-30	E	62.93	4.93	9.78
		(286.29)	(colourless)	(59)	(62.80	4.89	9.66)
4	6	$C_{18}H_{14}N_2O_3$	135-36	P 80-100	70.58	4.61	9.15
		(306.32)	(colourless)	(47)	(70.41	4.53	9.08)
5	6	$C_{25}H_{18}N_2O_4$	290-91	E	73.16	4.42	6.83
		(410.43)	(Brown)	(35)	(73.00	4.37	6.71)
6	8	$C_{16}H_{12}N_2O_2$	166-67	P 80-100	72.71	4.58	10.59
		(264.28)	(colourless)	(67)	(72.55	4.51	10.42)
7	36	$C_{29}H_{19}N_3O_4$	130-31	P 80-100	73.57	4.04	8.87
		(473.49)	(colourless)	(45)	(73.35	4.01	8.76)
8	7	$C_{20}H_{18}N_2O_3$	102-03	E	71.84	5.43	8.38
		(334.38)	(colourless)	(88)	(71.66	5.41	8.29)
9	8	$C_{20}H_{18}N_2O_5$	113-15	E	65.57	4.95	7.65
		(366.37)	(colourless)	(60)	(64.92	4.90	7.42)
10	10	$C_{22}H_{18}N_2O_3$	134-35	E	73.73	5.06	7.82
		(358.40)	(colourless)	(58)	(73.49	5.01	7.68)
11	9	$C_{17}H_{14}N_2O_2$	115-16	E	73.37	5.07	10.07
		(278.31)	(colourless)	(78)	(73.19	5.05	9.89)
12	7	$C_{17}H_{14}N_2O_3$	100-01	E	69.38	4.79	9.52
		(294.31)	(Orange)	(60)	(69.29	4.70	9.37)
13	8	$C_{18}H_{14}N_2O_2$	149-50	E	74.47	4.86	9.65
		(290.32)	(colourless)	(58)	(74.39	4.88	9.56)
14	0.5	$C_{18}H_{12}N_2O_3Cl_2$	185-86	P 60-80	57.62	3.22	7.47
		(375.21)	(Yellow)	(61)	(57.47	3.18	7.35)
15	0.5	$C_{23}H_{16}N_2O_3Cl_2$	224-25	P 80-100	62.89	3.67	6.38
		(439.30)	(Yellow)	(69)	(62.72	3.61	6.30)
16	0.5	$C_{22}H_{13}N_3O_3Cl_2$	166-67	P 80-100	60.29	2.99	9.59
		(438.27)	(colourless)	(73)	(60.13	2.91	9.45)
17	0.5	$C_{11}H_{12}N_2O_3S$	161-62	E	52.37	4.79	11.10
		(252.29)	(colorless)	(70)	(52.19	4.73	10.95)
18	0.5	$C_{16}H_{14}N_2O_3S$	149-50	E	61.13	4.49	8.91
		(314.37)	(colourless)	(73)	(60.98	4.46	8.77)
19	0.5	$C_{15}H_{13}N_3O_3S$	155-56	E	57.13	4.16	13.32
		(315.35)	(colourless)	(68)	(57.00	4.12	13.15)
20a	26	$C_{10}H_{10}N_4O_4$	230-31	E	48.00	4.03	22.39
		(250.21)	(Yellow)	(40)	(47.92	3.99	22.31)
20b	24	$C_{20}H_{14}N_4O_4$	216-18	E	64.17	3.77	14.97
		(374.36)	(colourless)	(75)	(64.05	3.73	14.85)

*P: petroleum ether; E: ethanol

Table III — Spectral data of compounds **1-20**

Compd	IR (ν in cm^{-1})	^{1}HNMR (Solvent, δ, ppm)
1a*	3320-3340 (OH or NH), 1650 (C=O of pyrazolinone ring), 1590-1605 (C=C or C=N)	(DMSO): 2.09 (s, 3H, CH_3), 3.35 (s, 1H, OH), 5.21 (s, 1H, C_4-H),10.32 (b,1H, NH)
1b*		(DMSO): 5.96 (s, 1H, C_4-H), 7.34 (s, 1H, OH), 7.40-7.73 (m, 5H, Ar-H),11.2 (b, 1H, NH)
1c*		(DMSO): 3.45 (s, 1H, OH), 6.03 (s, 1H, C_4-H), 7.44 (m, 1H, pyrid-C_5-H), 8.08 (d, 1H, Pyrid-C_4-H), 8.51 (d, 1H, Pyrid-C_6-H), 8.99 (s, 1H, Pyrid-C_2-H), 10.96 (b, 1H, NH)
2**	1610 (C=C, C=N), 1721 (C=O), 2998 (CH) and 3223 (NH)	($CDCl_3$): 2.21(s, 3H, CH_3), 2.74 (s, 3H, CH_3COO), 5.73 (s, 1H, C_4-H), 11.23 (b, 1H, NH)
3	1559 (C=C, C=N), 1643 (C=O), 1706 (C=O, 4-acetyl), 1744 (C=O), and 2852, 3071 (CH)	($CDCl_3$): 2.12 (s, 3H, N-$COCH_3$), 2.31 (s, 3H, C_4-$COCH_3$), 2.61 (m, 3H, CH_3COO), 7.41-7.82 (m, 5H, Ph-H)
4	1597 (C=C, C=N), 1702 (C=O), 2928, 3062 (CH)	($CDCl_3$): 2.73 (s, 3H, CH_3), 6.38 (s, 1H, C_4-H), 7.46-8.20 (m, 10H, Ph-H)
5	1593 (C=C, C=N), 1705 (C=O), 1747 (C=O), and 2872, 3075 (CH)	($CDCl_3$): 2.73 (s, 3H, CH_3), 7.47-8.20 (m, 15H, Ph-H)
6	1570 (C=C, C=N), 1746 (C=O), 2990, ,3007, 3109 (CH), 3365 (NH)	($CDCl_3$): 6.55 (s, 1H, C_4-H), 7.42-8.20 (m, 10H, Ph-H), 11.32 (b, 1H, NH)
7	1593 (C=C, C=N), 1705 (C=O), 1747 (C=O), 2872, 2997, 3105 (CH)	(DMSO): 7.45-8.45 (m, 15H, Ph-H), 8.82-10.16 (m, 4H, pyridyl-H)
8	1596 (C=C, C=N), 1717 (C=O), 2926, 2969, 3007, 3150 (CH)	($CDCl_3$): 2.41 (s, 3H, N-COAr-CH_3), 2.44 (s, 3H, O-COAr-CH_3) 2.71 (s, 3H, CH_3), 6.38 (s, 1H, C_4-H), 7.26-8.07 (m, 8H, Ar-H)
9	1585, 1604 (C=C, C=N), 1710(C=O), 2962, 3145 (CH)	($CDCl_3$): 2.47 (s, 3H, CH_3), 3.83 (s, 3H, N-COAr-OCH_3), 3.87 (s, 3H, O-COAr-OCH_3), 6.86 (s, 1H, C_4-H), 7.29-8.15 (m, 8H, Ar-H)
10	1592 (C=C, C=N), 1712 (C=O), 2961, 3127 (CH)	($CDCl_3$): 2.68 (s, 3H, CH_3), 6.32 (s, 1H, C_4-H), 6.94-8.17 (m, 4H, CH=CH,10H, Ph-H)
11	1591, 1692 (C=C, C=N), 1749(C=O), 2962, 3145 (CH), 3220 (NH)	($CDCl_3$): 3.92 (s, 3H, O-COAr-CH_3) 6.82 (s, 1H, C_4-H), 7.00-8.23 (m, 9H, Ar-H), 10.88 (b, 1H, NH)
12	1451, 1622 (C=C, C=N), 1736(C=O, ester), 3061, 3069 (CH), 3266 (NH)	($CDCl_3$): 3.87 (s, 3H, O-COAr-OCH_3), 6.31 (s, 1H, C_4-H), and 6.61-7.96 (m, 9Ar-H), 11.08 (b, 1H, NH)
13	1591, 1623 (C=C, C=N), 1739(C=O), 2852, 3035 (CH), 3257 (NH)	($CDCl_3$): 6.67 (s, 1H, C_4-H), and 6.85-8.04 (m, 12H, 10 Ph-H + CH=CH), 10.86 (b, 1H, NH)
14	1586 (C=C, C=N), 1723,1751 (C=O, ester), 2975, 3099 (CH)	($CDCl_3$): 2.72 (s, 3H, CH_3), 6.37 (s, 1H, C_4-H), 7.44-8.16 (m, 8H, Ar-H)
15	1586 (C=C, C=N), 1723,1751 (C=O, ester), and 2975, 3099 (CH)	($CDCl_3$): 6.70 (s, 1H, C_4-H), 7.4-8.0 (m, 13H, Ar-H)
16	1586 (C=C, C=N), 1723,1751 (C=O, ester), and 2975, 3099 (CH)	($CDCl_3$): 6.62 (s, 1H, C_4-H), 6.92-7.78 (m, 8H, Ar-H), 8.76-10.03 (m, 4H, pyridyl-H)
17	1183-1187 (SO_3), 1581-1579 (C=C, C=N), 2992, 3187 (CH), 3247 (NH)	($CDCl_3$): 2.29 (s, 3H, C5-CH_3), 2.46 (s, 3H, Ph-CH_3), 5.73 (s, 1H, C_4-H), 7.33 (d, 2H, Ar-H), 7.80 (d, 2H, Ar-H), and 11.24 (hidden, 1H, NH)
18	1183-1187 (SO_3), 1581-1579 (C=C, C=N), 2992, 3187 (CH), 3251 (NH)	($CDCl_3$): 2.40 (s, 3H, Ar-CH_3), 6.33 (s, 1H, C_4-H), 7.24-7.76 (m, 9H, Ar-H), and 11.36 (br, 1H, NH)
19	1183-1187 (SO_3), 1581-1579 (C=C, C=N), 2992, 3187 (CH), 3351 (NH)	($CDCl_3$): 2.43 (s, 3H, CH_3), 6.35 (s, 1H, C_4-H), 7.26-8.83 (m, 9H, Ar-H) and 11.63 (br, 1H, NH)
20a	1595 (C=C, C=N),1652 (C=O), 2865, 2990 (CH), broad 3307 (OH)	($CDCl_3$): 2.36 (s, 3H, CH_3), 2.58 (s, 3H, CH_3), 5.42 (s, 1H, C_4-H), 5.59 (s, 1H, C_4-H), 8.29 (s, 1H, OH), 9.15 (s, 1H, OH)
20b	1607(C=C, C=N), 1643 (C=O), 3061 (CH), broad 3320 (OH)	($CDCl_3$): 5.63 (s, 1H, C_4-H), 5.75 (s, 1H, C_4-H), 9.29 (s, 1H, OH), 9.61 (s, 1H, OH), 7.42-8.16 (m, 10H, Ph-H)

*The ^{13}CNMR (DMSO) spectrum of **1a** displayed signals at (δ, ppm): 11.84 (CH_3), 99.53 (C_4), 139.9 (C_3) and 161.6 (C_5). The ^{13}CNMR (DMSO) spectrum of **1b** showed signals at (δ, ppm): 87.59 (C_4), 125.4, 128.5, 129.5, 131.1 (phenyl carbons), 144.04 (C_3) and 161.74 (C_5). The ^{13}CNMR (DMSO) spectrum of pyrazole **1c** showed signals at (δ, ppm): 12.2 (CH_3), 34.3 (SCH_2), 60.9 (OCH_2), 111.8 (C_5), 127.6 -136.5 (Ph-C), 157.6 (C_4) ,159.7 (C_6), 161.6 (C_2), 166.3 (CO ester).

**The mass spectrum showed mass peaks at 140 (M^+, 22), 99 (6), 98 (100), 97 (45), 69 (10), 67 (17), and 55 (11).

(**1**, 0.01 mole), anhydrous potassium carbonate (0.02 mole, 2.76 g) and tetrabutylammonium bromide (TBAB, 0.003 mole, 0.9 g) in acetonitrile or dioxane (50 mL) was stirred at 25°C for 30 min, then the acetylating agent (0.03 mole), while, (0.01 mole) of oxalyl chloride was added and the reaction mixture was efficiently stirred at room temperature. The progress of the reaction was monitored by TLC during the entire reaction time. After completion of the reaction (disappearance of the spot of starting pyrazoles), the organic layer was separated by filtration and the solvent was evaporated. The residue was crystallized from the proper solvent or separated by column chromatography using silica gel (80-120 mesh) and proper eluent to give one or more pure products. Also, the K_2CO_3 precipitate was dissolved in water (100 mL) and acidified by dilute HCl (10%) to separate and identify the acidic products in the solid phase.

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