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Highly Effective And Environmentally Friendly One-Pot Synthesis Of Penta Substitute Pyrrole Derivatives Under Catalyst-Free Conditions

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ABSTRACT

An eco-friendly and effective one-pot synthesis of penta-substituted pyrrole derivatives via a four-component reaction of maldrum's acid, arylglyoxal monohydrate, dimethyl but-2-yne-dioate and amines under catalyst-free conditions in an environmentally friendly medium is described. The simple experimental procedure, catalyst-free reaction conditions, short period of conversion, and excellent yields are the advantages of the present method. Good chemical yields have been achieved without the need for chromatography and recrystallization or other purification methods.

Keywords:

One-pot synthesis, penta-substituted pyrrole derivatives, multi-component reactions

1. INTRODUCTION

The development of a simple, green reaction protocol for the synthesis bioactive medicinal motifs is an attractive area of research in both academia and the pharmaceutical industry. One of the most attractive approaches is to use of multi-component reactions (MCRs) using three or more starting materials in one-pot procedure to give a final complex product [1]. In the past decade, there have been tremendous developments in MCRs methodology and significant efforts continue to be made to develop new MCRs. Among the many heterocyclic compounds, the pyrrole ring has found a large number of applications and is present in many natural products. [2] It is used as an important skeleton in organic synthesis and is also utilized in other important fields, such as functional materials, [3] medicinal chemistry and pharmacological agents. Up to date, many synthetic methods have been developed for the construction of pyrroles, including the classical Knorr reaction, the Hantzsch reaction, [4] Buchwald–Hartwig coupling [5] and the Paal–Knorr condensation reaction. Additionally, other new methodologies, such as transition-metal catalyzed cyclizations, [6] cyclo-addition reactions [7] and MCRs were developed for preparing new pyrrole derivatives. However; some of these methods have significant limits such as boring workup procedures, harsh reaction conditions, low yields, long reaction times or the condition for an inert atmosphere. Therefore, a simple and efficient method for pyrrole synthesis remains an attractive goal. On the other side, 2-substituted maldrum's acid, derivatives are of much importance because they exist in many natural products and exhibit a wide range of biological activities such as antibacterial, antiviral,[8] anticoagulant, antiHIV, anticancer [9] and antioxidant activities [10]. A molecular scaffold which combines both maldrum's acid, and pyrrole moieties might integrate the properties of both, and the

hybridization of the both heterocyclic systems in a single nucleus may result in the formation of some valuable molecules from a biological viewpoint. To the best of our knowledge, there have been no reports of synthesis of maldrum's acid fused pyrrole derivatives by multi-component reactions. As a part of our ongoing research on the development of multi-component approaches to heterocycles, herein we are reporting new synthesis of penta-substituted pyrrole derivatives using MCRs.

2. RESULT AND DISCUSSION

We at first evaluated the four-component reaction of a 1 : 1 : 1 : 1 mixture of maldrum's acid (**1**), phenylglyoxal monohydrate (**2**), dimethyl but-2-ynedioate (**3**) and p-toluidine (**4**) under a variety of conditions (Scheme 1). The results are summarized in Table 1. To find the best reaction conditions, we evaluated several different parameters including reaction temperature, solvent, and additives. Firstly, the synthesis of target compound (**5a**) was performed in a variety of solvent like acetone, DMF, THF, ethyl acetate, water, and ethanol. To our delight, all the reactions gave moderate to excellent yield of the desired product except DMF, and ethayl acetate. The best results were obtained when ethanol was used as a solvent at reflux and the reaction proceeded excellent affording the desired product in 83% yield within 1 h (Table 1, entry 7). Recently L-proline has been used as a catalyst for some multi-component reactions. To optimize the reaction conditions and investigated the role of catalyst, L-proline was selected as the catalyst to promote this reaction. However, the use of L-proline as a catalyst showed no improvement in yield (Table 1, entry 8).

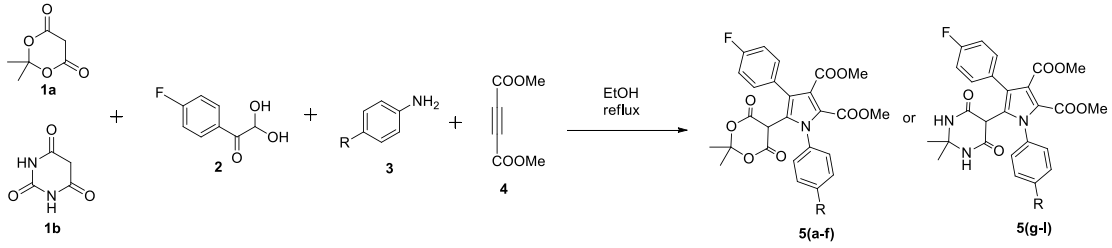
The optimized reaction conditions were then applied for the construction of library with maldrum's acid along with barbituric acid (1,3-dicarbonyl compounds), 4-F-phenylglyoxal monohydrates, dimethyl but-2-ynedioate, and six arometic amine. The corresponding penta-substituted pyrrole derivatives 5(b–l) were obtained refluxing ethanol under catalyst free conditions. The result showed that the reaction is seen to be tolerant of substitution on the aniline ring with electron-donating groups at C4- the position (Table 2). However, electron-withdrawing group present at the C4 position of aniline ring yielded compound with low yield (Table 2, entries 6 and12).

2.1 Experimental Procedure

2.1.1 Materials and methods:

^{1}H NMR spectra were recorded on a Bruker AV 3000 supercon (400 MHz) spectrometer using the deuterated solvent as an internal deuterium lock. Chemical shift data are given in units δ relative to residual protic solvent where δ ($CDCl_3$-*d*) = 7.24 ppm and δ (DMSO-d_6) = 2.50 ppm. The multiplicity of a signal is indicated as: br-broad, s-singlet, d-doublet, t-triplet, q-quartet, m-multiplet etc. Coupling constant (*J*) are quoted in Hz and recorded to the nearest 0.1 Hz. ^{13}C NMR Spectra were recorded on a Bruker AV 3000 supercon (100 MHz) spectrometer with broadband proton decoupling using the deuterated solvent as an internal deuterium lock. Chemical shift data are given in units δ relative to residual protic solvent where δ($CDCl_3$-*d*) = 77.23 ppm δ(DMSO-d_6) = 39.51 ppm.

2.1.2 Reaction Scheme



2.1.3 General procedure for the synthesis penta-substituted pyrrole

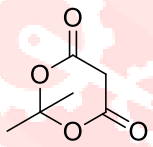
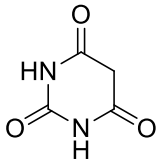
A dry 25 mL flask was charged with maldrum's acid **1a** (1 mmol), 4-F-phenylglyoxal monohydrate **2** (1 mmol) or barbituric acic **1b** (1 mmol), substituted anilines **3a-f** (1mmol), dimethyl but-2-ynedioate **4** (1 mmol), and ethanol (5mL). The mixture was stirred at refluxing temperature for indicated time. After the completion of the reaction (confirmed by TLC), the reaction mixture was cooled to room temperature. The crude product obtained was finally purified by recrystallization from chloroform. The isolated compounds were characterized by IR, ^{1}H NMR, ^{13}C NMR and elemental analysis (C, H and N).

Tabel 1. Optimization of the reaction conditions for the synthesis of compound (5a)

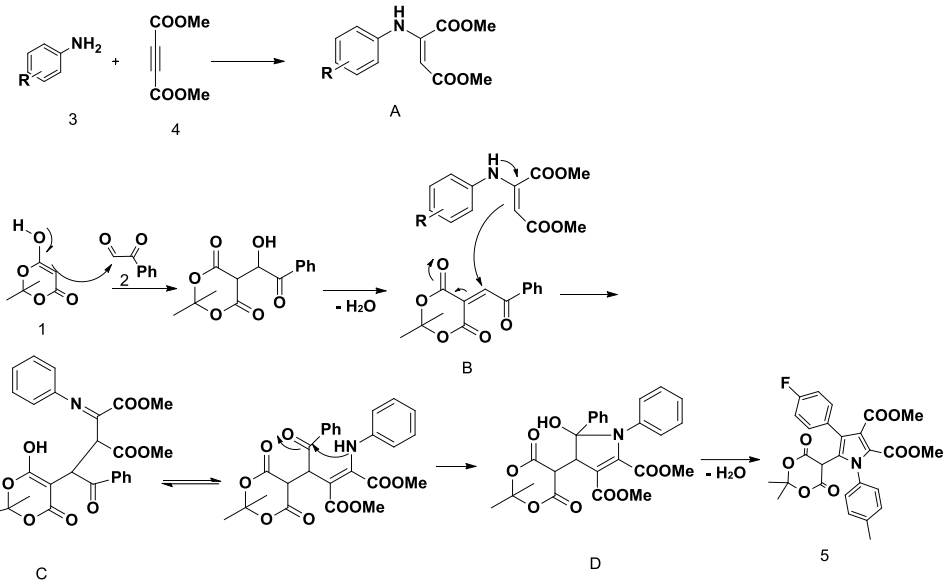
Entry	Solvent	Temperature (°C)	Additive	Time (h)	Yield[a,b] (%)
1	DMF	80	-	1	22
2	Acetone	60	-	1	56
3	Ethyl acetate	80	-	1	12
4	H_2O	80	-	1	45
5	THF	80	-	1	64
6	EtOH	r.t.	-	24	42
7	EtOH	80	-	1	83
8	EtOH	80	L-proline	1	81

[a]Reaction conditions:1a (1 mmol), 2 (1 mmol), 3 (1 mmol), 4 (1 mmol), solvent (5 mL). [b]Isolated yield.

Table 2. The synthesis of penta-substituted pyrrole derivatives 5(a-l)viafour-component reaction

Entry	1,3-Dicarbonyl compounds	R^1	Time (h)	Product	Yield (%)
1		4-$CH_3C_6H_4$	1.0	5a	83
2		4-Cl C_6H_4	3.0	5b	76
3		4-OCH_3 C_6H_4	1.2	5c	87
4		4-F C_6H_4	2.5	5d	72
5		4-Br C_6H_4	2.7	5e	76
6		4-NO_2 C_6H_4	4.2	5f	57
7		4-CH_3 C_6H_4	1.0	5g	86
8		4-Cl C_6H_4	2.7	5h	74
9		4-OCH_3 C_6H_4	1.2	5i	88
10		4-F C_6H_4	2.3	5j	71
11		4-Br C_6H_4	2.5	5k	72
12		4-NO_2 C_6H_4	3.8	5l	52

2.1.4 Proposed mechanism for the formation of compounds



2.1.5 Spectral data of the compounds

Dimethyl,5-(2,2-dimethyl-4,6-dioxo-1,3-dioxan-5-yl)-4-(4-fluorophenyl)-1-(p-tolyl)-1H-pyrrole-2,3-dicarboxylate (5a)

Characteristic: white crystalline solid M.P.: 146-150 ^{o}C ;IR (KBr): 3032, 2845, 1691, 1622, 1528, 1394, 1274, 1179, 753cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.76 (s, 6H, C(CH_3)$_2$), 2.27 (s, 3H, -CH_3), 3.65 (s, 6H(-$COOCH_3$), 5.01 (s, 1H -CH), 7.05 (d, 4H, *J* = 6.0 Hz, 2 × ArH), 7.09 (d, 2H 2 × ArH), 7.15 (d, 4H, *J*=6Hz, 2 × ArH) 7.18(d, 2H, 2 × ArH) ^{13}C NMR (75 MHz, $CDCl_3$): δ 27.1, 50.5, 50.9, 51.6, 104.8, 116.3, 118.5, 121.1, 122.7, 129.6, 135.8, 160.6, 162.9, 171.1 Anal. Calcd. for ($C_{27}H_{24}FNO_8$): C, 63.65; H, 4.75; F, 3.73; N, 2.75; O, 25.12. Found. C,62.16; H, 4.77; F, 3.23,N, 2.70

dimethyl1-(4-chlorophenyl)-5-(2,2-dimethyl-4,6-dioxo-1,3-dioxan-5-yl)-4-(4-fluorophenyl)-1H-pyrrole-2,3-dicarboxylate (5b)

Characteristic: white crystalline solid M.P.: 166-170 ^{o}C ;IR (KBr): 3051, 2945, 1682, 1522, 1513, 1294, 1174, 1072, 825,753,cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.62 (s, 6H, C(CH_3)$_2$), 3.54 (s, 6H(-$COOCH_3$), 5.51 (s, 1H -CH), 7.15 (d, 4H, *J* = 6.0 Hz, 2 × ArH), 7.19 (d, 2H 2 × ArH), 7.19 (d, 4H, *J*=6Hz, 2 × ArH) 7.28(d, 2H, 2 × ArH) ^{13}C NMR (75 MHz, $CDCl_3$): δ 27.1, 50.5, 50.9, 51.6, 104.8, 116.3, 118.5, 121.1, 122.7, 129.6, 135.8, 160.6, 162.9, 171.1 Anal. Calcd. for ($C_{26}H_{21}ClFNO_8$): C, 58.93; H, 3.99; N, 2.64 Cl, 6.69; F, 3.59 O, 24.15. Found. C, 58.53; H, 3.59; N, 2.24 Cl, 7.59; F, 3.17 O, 23.12.

dimethyl5-(2,2-dimethyl-4,6-dioxo-1,3-dioxan-5-yl)-4-(4-fluorophenyl)-1-(4-methoxyphenyl)-1H-pyrrole-2,3-dicarboxylate(5c)

Characteristic: white crystalline solid M.P.: 119-122 ^{o}C ;IR (KBr): 3022, 2825, 1671, 1625, 1531, 1354, 1242, 1129, 753,748,cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.65 (s, 6H, C(CH_3)$_2$), 3.72 (s, 3H, -CH_3), 3.82 (s, 6H(-$COOCH_3$), 5.08 (s, 1H -CH), 7.37 (d, 4H, *J* = 6.0 Hz, 2 × ArH), 7.39 (d, 2H 2 × ArH), 7.39 (d, 4H, *J*=6Hz, 2 X ArH) 7.49(d, 2H, 2 × ArH) ^{13}C NMR (75 MHz, $CDCl_3$): δ 27.1, 51.5, 52.6,, 105.8, 108.3, 117.5, 121.6, 133.7, 134.6, 136.8, 141.6, 160.9, 162.1,163.4,177.2Anal. Calcd. for ($C_{27}H_{24}FNO_9$): C, 61.71; H, 4.60; F, 3.62; N, 2.67; O, 27.40 Found. C, 60.93; H, 3.99; N, 2.64; F, 3.59 O, 26.15.

dimethyl5-(2,2-dimethyl-4,6-dioxo-1,3-dioxan-5-yl)-1,4-bis(4-fluorophenyl)-1H-pyrrole-2,3-dicarboxylate(5d)

Characteristic: white crystalline solid M.P.: 162-164 ^{o}C; IR (KBr): 3036, 2844, 1639, 1622, 1572, 1312, 1247, 1197,824,763, cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1. 67 (s, 6H, C(CH_3)$_2$), 3.90 (s, 6H(-$COOCH_3$), 4.91 (s, 1H -CH), 7.24 (d, 4H, *J* = 6.0 Hz, 2 × ArH), 7.30 (d, 2H 2 × ArH), 7.36 (d, 4H, *J*=6Hz, 2 × ArH) 7.60(d, 2H, 2 × ArH) ^{13}C NMR (75 MHz, $CDCl_3$): δ

29.1,51.5,104.8,116.0,116.5,121.7,123.6,128.4,130.2,160.1,162.9,165.7,172.3 Anal. Calcd. for ($C_{26}H_{21}F_2NO_8$): C, 60.82; H, 4.12; F, 7.40; N, 2.73; O, 24.9 Found. C, 60.53; H, 4.99; N, 2.64; F, 7.59 O, 24.15.

dimethyl5-(2,2-dimethyl-4,6-dioxo-1,3-dioxan-5-yl)-4-(4-fluorophenyl)-1-(4-nitrophenyl)-1H-pyrrole-2,3-dicarboxylate(5e)

Characteristic: white crystalline solid M.P.: 146-150 ºC ;IR (KBr): 3032, 2845, 1691, 1622, 1528, 1394, 1274, 1179, 753cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.67 (s, 6H, $C(CH_3)_2$), 4.01 (s, 6H(-$COOCH_3$), 4.41 (s, 1H -CH), 7.30 (d, 4H, *J* = 6.0 Hz, 2 × ArH), 7.39 (d, 2H 2 × ArH), 7. 51 (d, 4H, *J*=6Hz, 2 × ArH) 7.60(d, 2H, 2 × ArH) ^{13}CNMR(75MHz,$CDCl_3$):δ29.2,45.3,47.1,101.4,116.2,117.4,120.0,122.4,123.6,128.4,132.1,134.5,141.7,162.3,168.1,172.2 Anal. Calcd. for ($C_{26}H_{21}BrFNO_8$): C, 57.78; H, 3.92; F, 3.52;Br 2.41;N, 5.18; O, 29.60 Found. C, 58.93; H, 3.79; N, 5.64; F, 3.34; Br,2.72; O, 28.15.

dimethyl1-(4-bromophenyl)-5-(2,2-dimethyl-4,6-dioxo-1,3-dioxan-5-yl)-4-(4-fluorophenyl)-1H-pyrrole-2,3-dicarboxylate(5f)

Characteristic: white crystalline solid M.P.: 146-150 ºC ;IR (KBr): 3022, 2835, 1674, 1617, 1546, 1214, 1201, 1165,1023,865, 753cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.67 (s, 6H, $C(CH_3)_2$), 3.91 (s, 6H(-$COOCH_3$), 5.06 (s, 1H -CH), 7.32 (d, 4H, *J* = 6.0 Hz, 2 × ArH), 7.37 (d, 2H 2 × ArH), 7.68 (d, 4H, *J*=6Hz, 2 × ArH) 8.18(d, 2H, 2 × ArH)^{13}CNMR(75MHz,$CDCl_3$):δ28.1,51.3,104.5,116.0,121.9,124.5,127.1,130.8,134.1,144.7,160.1,162.9,173.1Anal.Calcd.for ($C_{26}H_{21}FN_2O_{10}$): C, 54.37; H, 3.69; Br, 13.91; F, 3.31; N, 2.44; O, 22.29 Found. C, 54.93; H, 3.99; N, 2.64; Br, 13.52,F, 3.59 O, 22.75.

dimethyl,4-(4-fluorophenyl)-1-(p-tolyl)-5-(2,4,6-trioxohexahydropyrimidin-5-yl)-1H-pyrrole-2,3-dicarboxylate (5g)

Characteristic: white crystalline solid (b) **M.P.:** 155-161 ºC ;**IR (KBr):** 3027, 2835, 1671, 1615, 1548, 1364, 1224, 1079, 743cm^{-1}; **^{1}H NMR (400 MHz, $CDCl_3$):** δ 2.27 (s, 3H, -CH_3), 3.62-3.64(s, 6H(-$COOCH_3$), 4.66(s, 1H -CH), 7.08(d, 4H, *J*=6Hz, 2 × ArH), 7.15(d, 2H 2 × ArH), 7.24(d, 4H, *J*=6Hz, 2 × ArH)7.39(d, 2H, 2 × ArH) 10.03 (1H, s, exchangeable, NH). **^{13}C NMR (75 MHz, $CDCl_3$):** δ 27.1, 50.5, 50.9, 51.6, 104.8, 116.3, 118.5, 121.1, 122.7, 129.6, 135.8, 160.6, 162.9, 171.1;Anal. Calcd. for ($C_{25}H_{20}FN_3O_7$): C, 57.78; H, 3.92; F, 3.52; N, 5.18; O, 29.60 Found. C, 57.36; H, 3.64; N, 5.58; ,F, 3.12 O, 29.15.

dimethyl1-(4-chlorophenyl)-4-(4-fluorophenyl)-5-(2,4,6-trioxohexahydropyrimidin-5-yl)-1H-pyrrole-2,3-dicarboxylate(5h)

Characteristic: white crystalline solid (b) **M.P.:** 159-163 ºC ;**IR (KBr):** 3025, 2935, 1691, 1625, 1542, 1354, 1324,1201, 1069,864, 743cm^{-1}; **^{1}H NMR (400 MHz, $CDCl_3$):** δ 3.73(s, 6H(-$COOCH_3$), 5.85(s, 1H -CH), 7.18(d, 4H, *J*=6Hz, 2 × ArH), 7.25(d, 2H 2 × ArH), 7.34(d, 4H, *J*=6Hz, 2 × ArH)7.49(d, 2H, 2 × ArH) 10.13 (1H, s,exchangeable,NH).**^{13}CNMR(75MHz,$CDCl_3$):**δ51.3,116.2,120.7,121.8,126.1,128.3,129.4,131.1,162.9,163.3Anal.Calcd.for ($C_{24}H_{17}ClFN_3O_7$): C, 56.10; H, 3.33; Cl, 6.90; F, 3.70; N, 8.18; O, 21.80Found. C, 56.93; H, 3.42; Cl, 6.75N, 2.64; F, 3.59 O, 24.15.

dimethyl4-(4-fluorophenyl)-1-(4-methoxyphenyl)-5-(2,4,6-trioxohexahydropyrimidin-5-yl)-1H-pyrrole-2,3-dicarboxylate(5i)

Characteristic: white crystalline solid (b) **M.P.:** 147-151 ºC ;**IR (KBr):** 3037, 2935, 1699, 1625, 1568, 1354, 1224,1102, 1049,875, 743cm^{-1}; **^{1}H NMR (400 MHz, $CDCl_3$):** δ 3.38 (s, 3H, -CH_3), 3.91 (s, 6H(-$COOCH_3$), 4.96(s, 1H -CH), 6.99(d, 4H, *J*=6Hz, 2 × ArH), 7.15(d, 2H 2 × ArH), 7.24(d, 4H, *J*=6Hz, 2 × ArH)7.31(d, 2H, 2

×ArH)10.02(1H,s,exchangeable,NH).**^{13}CNMR(75MHz,CDCl$_3$):**δ51.5,55.8,114.9,116.2,120.3,121.9,126.5 ,127.2,130.3,141.0,159.3,162.4,169.8; Anal. Calcd. for ($C_{25}H_{20}FN_3O_8$): C, 58.94; H, 3.96; F, 3.73; N, 8.25; O, 25.12.Found. C, 58.93; H, 3.99; N, 2.64; F, 3.59 O, 24.15.

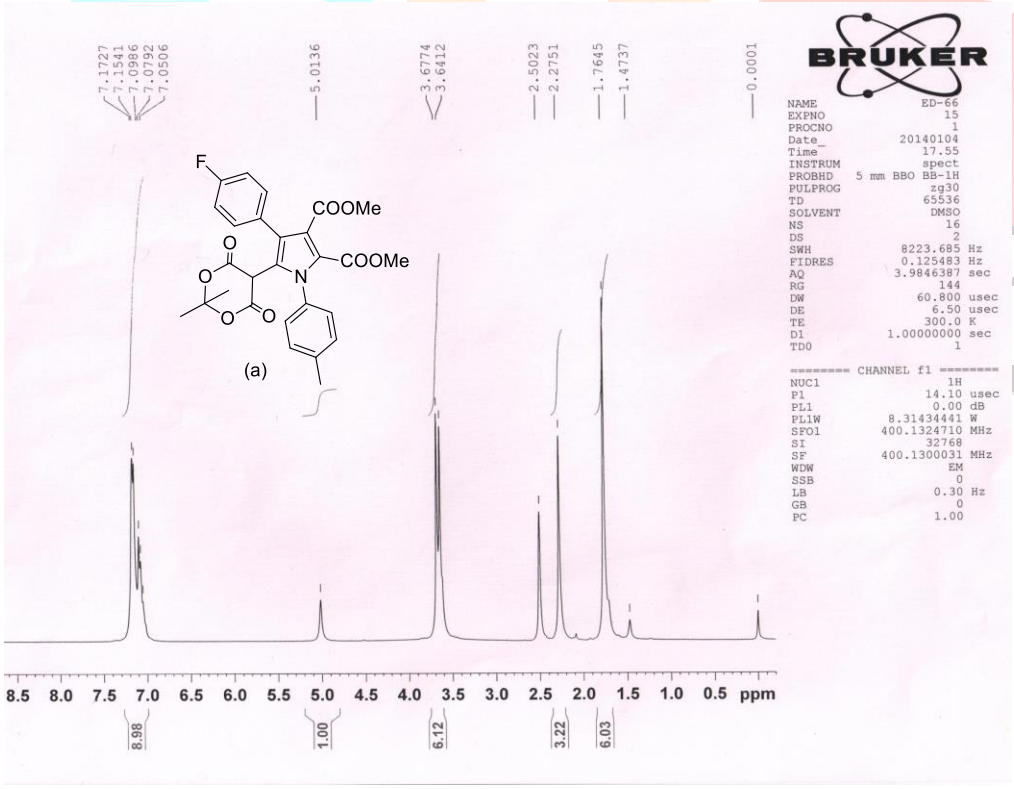
dimethyl1,4-bis(4-fluorophenyl)-5-(2,4,6-trioxohexahydropyrimidin-5-yl)-1H-pyrrole-2,3-dicarboxylate(5j)

Characteristic: white crystalline solid (b) **M.P.:** 171-174 ^{o}C ;**IR (KBr):** 3036, 2844, 1689, 1622, 1572, 1312, 1247, 1197,824,763 cm^{-1}; **^{1}H NMR (400 MHz, CDCl$_3$):** 3.72(s, 6H(-COOCH$_3$), 4.86(s, 1H -CH), 7.18(d, 4H, *J*=6Hz, 2 × ArH), 7.25(d, 2H 2 × ArH), 7.34(d, 4H, *J*=6Hz, 2 × ArH)7.39(d, 2H, 2 × ArH) 10.13 (2H, s, exchangeable, NH). **^{13}C NMR (75 MHz, CDCl$_3$):** δ 50.5, 114.8, 116.3, 120.5, 121.1, 122.7, 129.6, 135.8,141.5,159.2,160.6,162.9,171.1; Anal. Calcd. for ($C_{24}H_{17}F_2N_3O_7$): C, 57.95; H, 3.44; F, 7.64; N, 8.45; O, 22.52.Found. C, 58.93; H,3.99; F, 3.59 N, 2.64O, 24.15.

dimethyl1-(4-bromophenyl)-4-(4-fluorophenyl)-5-(2,4,6-trioxohexahydropyrimidin-5-yl)-1H-pyrrole-2,3-dicarboxylate(5k)

Characteristic: white crystalline solid (b) **M.P.:** 159-164 ^{o}C ;**IR (KBr):** 3077, 2854, 1686, 1614, 1554, 1394, 1221,1154,1032, 1019,864,723cm^{-1}; **^{1}H NMR (400 MHz, CDCl$_3$):**δ3.81(s, 6H(-COOCH$_3$), 4.87(s, 1H -CH), 7.17(d, 4H, *J*=6Hz, 2 × ArH), 7.23(d, 2H 2 × ArH), 7.32(d, 4H, *J*=6Hz, 2 × ArH)7.49(d, 2H, 2 × ArH) 10.0 (1H, s, exchangeable, NH). **^{13}C NMR (75 MHz, CDCl$_3$):** δ 51.6, 114.9, 116.3, 118.5, 121.4, 122.4, 128.6, 133.8,142.3,153.2, 160.6, 162.9, 170.1; Anal. Calcd. for ($C_{24}H_{17}BrFN_3O_7$): C, 51.63; H, 3.07; Br, 14.31; F, 3.40; N, 7.53; O, 20.06Found. C, 58.93; H, 3.99; Br,14.31; F, 3.59 N, 2.64O, 24.15.

^{1}H NMR spectra



3. CONCLUSION

In summary, we have developed an exceedingly simple, mild, clean and expeditious synthetic protocol for penta substituted pyrroles derivatives. Remarkable advantages of this synthetic strategy over the others are (i) high yields, (ii) no need of acid/base catalyst and solvent, (iii) decreased reaction times, (iv) simplified work-up procedure, and (v) ambient reaction temperature

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