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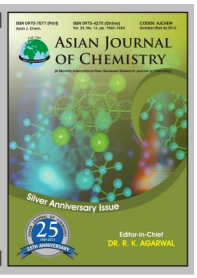

Synthesis of Novel Arylfurfurylchalcones

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Various aryl furans-2-carbaldehyde chalcones with different acetophenones were prepared and characterized through their elemental analyses and spectroscopic techniques (FTIR, ^{1}H NMR, ^{13}C NMR and mass spectra).

Key Words: Aryl furans, Meerwein-arylation, Chalcones.

INTRODUCTION

Nitro group containing furans such as dantrolene, a muscle relaxant and nitrofurantoin an antibiotic are in clinical use[1] while other derivatives find diverse applications in industry[2-4]. Yet other substituted furan-2-carbaldehydes possess a C 2 cabonyl group that may act as a reactive centre for various condensation reactions. Many of the published condensations products are biologically active compounds[5,6] or can be used as intermediates in organic synthesis[7,8].

Chalcones, α,β-unsaturated ketones[9-11] display a wide range of pharmaceutical properties, including cytotoxity[12, 13], antimitotic[14], antimutagenic[15] antitumor-promoting, antibacterial[16], antiviral[17] and anti-inflammatory[18] activities. They are also useful in material science fields such as non-linear optics (NLO)[19], optical limiting[20], electrochemical sensing[21], Langmuir films and photo-initiated polymerization[22]. Various chalcone derivatives are notable materials for their second harmonic generation (SHG)[23]. They are well known intermediates for synthesizing various heterocyclic compounds. Cyclization of chalcones, leading to various heterocycles, such as thiazines, pyrimidines, pyrazoline etc. which have potentials as efficacious antibacterial agents. A survey of literature in the recent past reveals that some pyrazoline derivatives possess antibacterial[24,25], anti-inflammatory[26,27] and antifungal effects[28].

Some 1-aryl-3-[5-(*p*-nitrophenyl)-2-propen-1-ones were obtained from the corresponding 5-*p*-nitrophenylfuran-2-carbaldehyde are reported and were used for the synthesis of 1,2,4-triazolo[3,4-b]-1,3,4-thiadiazines claimed to have antibacterial and antiviral properties[29]. We would now like to report the synthesis of numerous new 1-aryl-3-arylfurylpropenes which are currently under investigation for their biological screening.

EXPERIMENTAL

All reagents and solvents were used as obtained from the supplier or recrystallized or redistilled as necessary. Thin layer chromatography was performed using aluminium sheets (Merck) coated with silica gel 60 F_{254}. IR spectra were recorded by using an IR Perkin-Elmer spectrum 1 FTIR spectrophotometer. Proton magnetic resonance spectra were recorded in $CDCl_3$ with Bruker AM 300 spectrometers (Rheinstetten-Forchheim, Germany) operating at 300 MHz, respectively. The ^{13}C NMR spectra were recorded in $CDCl_3$ with Bruker AM 100 spectrometer operating at 100 MHz. Tetramethyl-silane was used as an internal standard. Elemental analyses for C, H and N were recorded with Perkin-Elmer 2400 Series II CHN Analyzer. Melting points were recorded on a GallenKamp apparatus and are uncorrected.

Synthesis of 5-arylfuran-2-carbaldehydes[30]: 4.5 g of substituted aniline was dissolved in a mixture of conc. hydrochloric acid and 20 mL of water under stirring and cooled in an ice bath at -5 ºC. A solution of sodium nitrite (2 g in 10 mL of water) was added portion wise, keeping the temperature below 7-8 ºC. The reaction mixture was left for 1 h for the completion of diazotization, filtered with the help of glass wool (if there is any turbidity observed). Then to the solution of furan-2-carbaldehyde (2 mL in 10 mL of acetone and water), the diazonium solution was added drop wise followed by a solution of copper chloride (2 g in 10 mL of water). The

TABLE-1
PHYSICAL DATA FOR THE ARYLFURAN-2-CARBALDEHYDES

Compound	R	Yield (%)	m.p. (ºC)	m.w.	m.f.	Elemental analysis (%): Calcd. (found)		
						C	H	N
1	2-NO_2	67.00	80-81	217	$C_{11}H_7NO_4$	60.81 (60.85)	3.22 (3.34)	6.45 (6.51)
2	3-NO_2	61.00	148	217	$C_{11}H_7NO_4$	60.81 (60.92)	3.22 (3.29)	6.45 (6.40)
3	4-NO_2	64.00	196	217	$C_{11}H_7NO_4$	60.81 (60.86)	3.22 (3.34)	6.45 (6.52)
4	2-Cl	58.00	72	206, 208	$C_{11}H_7ClO_2$	64.06 (63.96)	3.39 (3.43)	-
5	3-Cl	55.00	104	206, 208	$C_{11}H_7ClO_2$	64.06 (64.12)	3.39 (3.45)	-
6	4-Cl	62.00	118	206, 208	$C_{11}H_7ClO_2$	64.06 (64.09)	3.39 (3.44)	-
7	4-Br	61.00	150	250, 252	$C_{11}H_7BrO_2$	52.62 (52.66)	2.80 (2.84)	-
8	4-COOH	57.00	296	216	$C_{12}H_8O_4$	66.66 (66.71)	3.70 (3.76)	-

TABLE-2
FTIR AND ^{1}H NMR DATA OF ARYLFURAN-2-CARBALDEHYDE

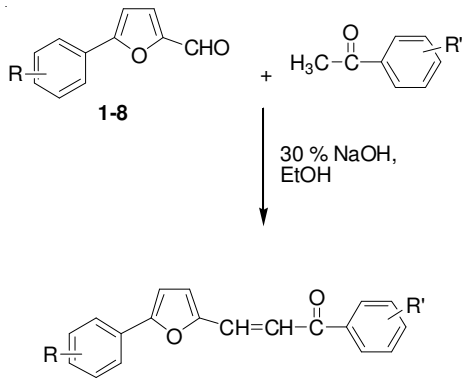
Compound	IR (cm^{-1})	NMR data δ (ppm)
1	1669.69 (C=O), 1510.01 and 1355.83 (Asym and sym -NO_2), 2363.67 (aromatic ring), 2846.65 (C-H stretch of aldehyde)	^{1}H NMR: 9.671 (s, 1H, CHO), 7.30 (d, 1H, furyl proton), 6.780 (d, 1H, furyl proton), 7.836-7.531 (m, 4H, Ar-H,); ^{13}C NMR: 177.72 (C=O aldehyde), 153.37, 152.93, 132.41, 130.31, 130.07, 126.65, 124.32, 122.99, 121.83, 112.03 (Ar-C)
2	1678.69(C=O), 1504.32 and 1359.64 (Asym and sym -NO_2), 2361.51 (aromatic ring)	^{1}H NMR: 9.709 (s, 1H, Ar-CHO), 7.350 (d, 1H, furyl proton), 6.994 (d, 1H, furyl proton), 8.614 (s, 1H, Ar-H), 8.232 (d, 1H, Ar-H), 8.142 (d, 1H, Ar-H), 7.655 (t, 1H, Ar-H); ^{13}C NMR: 177.49 (C=O aldehyde), 157.81, 152.74,146.67, 133.94, 132.78, 130.62, 130.20, 128.82, 120.06, 109.99 (Ar-C)
3	1667.75 (C=O) 1514.12 and 1327.56 (Asym and sym -NO_2), 2363.49 (aromatic ring)	^{1}H NMR: 9.720 (s, 1H, Ar-CHO), 7.350 (d, 1H, furyl proton), 7.016 (d, 1H, furyl proton), 8.311 (d, 2H, Ar-H) 7.972 (d, 2H, Ar-H); ^{13}C NMR: 177.55 (C=O aldehyde), 152.87, 151.67, 146.18, 132.09, 129.76, 127.88, 125.75, 124.42, 122.72, 110.61 (Ar-C)
4	1670.01(C=O), 2359.12 (Aromatic ring), 1089.91 (C-Cl)	^{1}H NMR: 9.659 (s, 1H, Ar-CHO), 7.308 (d, 1H, furyl proton), 6.850 (d, 1H, furyl proton), 7.796 (d, 1H, Ar-H), 7.679 (t, 1H, Ar-H), 7.369 (t, 2H, Ar-H); ^{13}C NMR: 177.49 (C=O aldehyde), 155.43, 151.56, 131.55, 130.95, 130.17, 129.15, 127.62, 127.17, 122.87, 113.19 (Ar-C)
5	1669.52 (C=O) 2360.04 (Aromatic ring), 2833.99 (C-H stretch of aldehydes), 1097.98 (C-Cl)	^{1}H NMR: 9.681 (s, 1H, Ar-CHO), 7.460 (d, 1H, furyl proton),7.994 (d, 1H, Ar-H), 7.299 (d, 1H, furyl proton), 7.383 (m, 2H, Ar-H), 7.235 (d, 1H, Ar-H); ^{13}C NMR: 177.35 (C=O aldehyde), 152.35, 135.16, 130.67, 130.28, 129.61, 125.28, 123.34, 123.06, 112.65, 108.50 (Ar-C)
6	1661.78 (C=O), 2360.11 (aromatic ring), 1094.28 (C-Cl)	^{1}H NMR: 9.639 (s, 1H, Ar-CHO), 7.293 (d, 1H, furyl proton), 6.808 (d, 1H, furyl proton), 7.750 (d, 2H, Ar-H,) 7.417 (d, 2H, Ar-H); ^{13}C NMR: 177.21 (C=O aldehyde), 158.20, 152.14, 135.66, 129.26, 127.45, 126.50, 123.41, 107.96 (Ar-C)
7	1661.73(C=O), 2863.39 (C-H stretch of aldehyde), 2360.38 (aromatic ring), 1041.23 (C-Br bond)	^{1}H NMR: 9.641 (s, 1H, Ar-CHO), 7.240 (d, 1H, furyl proton), 6.829 (d, 1H, furyl proton), 7.682-7.290 (m, 4H, Ar-H); ^{13}C NMR: 177.25 (C=O aldehyde), 132.24, 127.92, 126.72, 123.96, 123.69, 123.33, 108.06, 108.01 (Ar-C)
8	2360.14 (aromatic ring), 1672.39 (C=O acid), 2968.44 (-OH acid) 1610.63 (C=O aldehyde)	^{1}H NMR: 9.567 (s, 1H, Ar-CHO), 7.797 (d, 1H, Ar-H), 7.877 (d, 1H, Ar-H), 7.288 (d, 1H, Ar-H), 8.021 (d, 1H, Ar-H), 6.893 (d, 1H, furyl proton), 7.238 (s, 1H, furyl proton) ^{13}C NMR: 178.51 (C=O aldehyde), 165.96 (C=O of COOH) 155.43, 153.90, 132.46, 127.65, 123.87, 122.43, 122.09, 117.78, 109.89 (Ar-C)

temperature was raised to 30 ºC by heating (if necessary) and stirred for 4-6 h then left for 24 h at room temperature. Precipitates obtained were filtered, dried and recrystallized from ethanol. Furan-2-carbaldehydes thus prepared are listed in Table-1 and their spectral data in Table-2.

Synthesis of chalcones: Equimolar quantities of an arylfuran-2-carbaldehyde and appropriate acetophenone was taken in ethanol and water mixture (10 mL ethanol + 10 mL water) in the presence of 6 g of NaOH as a catalyst in ice bath (-5 ºC) and the mixture was stirred for 4 h. Solid product formed was filtered, dried and recrystallized from ethanol. The chalcones thus prepared are listed in the Table-3 and their spectral data in the Table-4 (**Scheme-I**).

RESULTS AND DISCUSSION

A convenient method for the synthesis of arylfurfural is based on the catalytic arylation of furfural with arenediazonium salts in 40-70 % yield which is fairly good for this reaction. The best yields in the arylation of furfural were obtained with diazonium salts containing a nitro group or two halogen atoms in the aromatic ring. In the present work, we synthesized different chalcones of arylfurfural with various acetophenones using basic catalyst (NaOH) according to Claisen-Schmidt condensation.



Scheme-I

TABLE-3
PHYSICAL DATA FOR THE CHALCONES

Compd.	Yield (%)	m.p. (ºC)	m.w.	m.f.	Elemental analysis (%): Calcd. (found)			R	R'
					C	H	N		
9	71	172*	319	$C_{19}H_{13}NO_4$	71.47 (71.27)	4.07 (3.90)	4.38 (4.36)	4-NO_2	H
10	68	126	308, 310	$C_{19}H_{13}ClO_2$	74.02 (73.90)	4.22 (4.18)	-	4-Cl	H
11	77	140	352, 354	$C_{19}H_{13}BrO_2$	64.77 (64.91)	3.69 (3.44)	-	4-Br	H
12	72	136	319	$C_{19}H_{13}NO_4$	71.47 (71.43)	4.07 (4.01)	4.38 (4.20)	3-NO_2	H
13	69	200 d	318	$C_{20}H_{14}O_4$	75.47 (75.34)	4.40 (4.24)	-	4-COOH	H
14	80	238	397, 399	$C_{19}H_{12}BrNO_4$	57.43 (57.47)	3.02 (2.98)	3.52 (3.59)	4-Br	4-NO_2
15	73	192 d	364	$C_{19}H_{12}N_2O_6$	62.63 (62.60)	3.29 (3.15)	7.69 (7.63)	3-NO_2	4-NO_2
16	72	200 d	364	$C_{19}H_{12}N_2O_6$	62.63 (62.65)	3.29 (3.33)	7.69 (7.65)	2-NO_2	4-NO_2
17	65	188	353	$C_{19}H_{12}ClNO_4$	64.58 (64.55)	3.39 (3.32)	3.96 (3.91)	3-Cl	4-NO_2
18	70	150 d	353, 355	$C_{19}H_{12}ClNO_4$	64.58 (64.49)	3.39 (3.34)	3.96 (3.92)	4-Cl	4-NO_2
19	76	228 d	364	$C_{19}H_{12}N_2O_6$	62.63 (62.56)	3.29 (3.36)	7.69 (7.72)	4-NO_2	4-NO_2
20	68	140 d	353, 355	$C_{19}H_{12}ClNO_4$	64.58 (64.50)	3.39 (3.28)	3.96 (3.92)	2-Cl	4-NO_2
21	65	134-36	342	$C_{19}H_{12}Cl_2O_2$	66.66 (66.71)	3.50 (3.46)	-	4-Cl	4-Cl
22	71	138-40	353, 355	$C_{19}H_{12}ClNO_4$	64.58 (64.54)	3.39 (3.35)	3.96 (3.89)	2-NO_2	4-Cl
23	63	144-46	-	$C_{19}H_{11}BrClO_2$	59.06 (58.95)	3.10 (2.95)	-	4-Br	4-Cl
24	62	118	-	$C_{19}H_{12}Cl_2O_2$	66.66 (66.75)	3.50 (3.37)	-	2-Cl	4-Cl
25	67	98	-	$C_{19}H_{12}Cl_2O_2$	66.66 (66.60)	3.50 (3.43)	-	3-Cl	4-Cl
26	73	200 d	352, 354	$C_{20}H_{13}ClO_4$	68.18 (68.13)	3.69 (3.61)	-	4-COOH	4-Cl
27	75	160	397, 399	$C_{19}H_{12}BrNO_4$	57.43 (57.28)	3.02 (2.97)	3.52 (3.42)	3-NO_2	4-Br
28	71	158	-	$C_{19}H_{12}Br_2O_2$	52.90 (52.95)	2.79 (2.83)	-	4-Br	4-Br
29	81	146	353, 355	$C_{19}H_{12}ClNO_4$	64.58 (64.61)	3.39 (3.32)	3.96 (3.89)	4-Cl	3-NO_2
30	76	148	364	$C_{19}H_{12}N_2O_6$	62.63 (62.69)	3.23 (3.29)	7.69 (7.62)	2-NO_2	3-NO_2

*lit.[28] m.p. 170 ºC

TABLE-4
FTIR AND ^{1}H NMR DATA OF CHALCONE

Compound	IR (cm^{-1})	NMR data δ (ppm)
9	2341.12 (Aromatic ring) 1664.91 (C=O conjugated carbonyl group), 1593.85 (C=C conjugated) 1562.44 and 1326.24 (Asym and sym -NO_2).	^{1}H NMR: 8.539 (d, 1H, Ar-H), 7.701 (d, 1H, Ar-H), 7.610 (d, 1H, Ar-H), 7.572 (d, 1H, Ar-H), 7.523 (d, 1H, Ar-H), 7.486 (d, 1H, Ar-H), 7.404 (d, 1H, ethylenic), 7.220 (d, 1H, ethylenic), 6.801 (d, 1H, furyl proton), 6.764 (d, 1H, furyl proton); ^{13}C NMR: 189.56 (C=O), 132.99, 128.48 (C=C), 153.58, 152.96,142.35, 141.46, 138.05, 135.36, 129.90, 129.28 128.72, 124.46, 120.59, 118.37, 111.63 (Ar-C).
10	2363.83 (Aromatic ring) 1646.14 cm^{-1} (C=O conjugated carbonyl group), 1585.50 cm^{-1} (C=C conjugated) 1572.71 cm^{-1} and 1338.06 (Asym and sym -NO_2), 1092.68 cm^{-1} (C-Cl bond).	^{1}H NMR: 8.048 (d, 1H, Ar-H), 7.701 (d, 1H, Ar-H), 7.610 (d, 1H, Ar-H), 7.572 (d, 1H, Ar-H), 7.523 (d, 1H, Ar-H), 7.486 (d, 1H, Ar-H), 7.404 (d, 1H, ethylenic), 7.458 (d, 1H, ethylenic), 6.801 (d, 1H, furyl proton), 6.764 (d, 1H, furyl proton); ^{13}C NMR: 189.78 (C=O) 130.34, 129.15, (C=C), 155.24, 151.43 138.30, 134.40, 132.74, 128.63, 128.43, 125.69, 119.12, 118.69, 108.59 (Ar-C).
11	2981.98 cm^{-1} (-OH), 1651.68 cm^{-1} (C=O), 2359.79 cm^{-1} (Aromatic ring), 1031.12 cm^{-1} (C-Br bond).	^{1}H NMR: 8.047 (d, 1H, Ar-H), 7.735-7.486 (m, 8H, Ar-H), 7.474 (d, 1H, ethylenic), 7.461 (d, 1H, ethylenic), 6.799 (d, 1H, furyl proton), 6.776 (d, 1H, furyl proton); ^{13}C NMR: 189.77 (C=O), 130.34, 128.71 (C=C) 155.23, 151.43, 138.24, 132.77, 132.07, 128.63, 128.43, 125.89, 122.56, 119.09, 118.77, 108.70 (Ar-C).
12	2364.56 cm^{-1} (Aromatic ring) 1659.63 cm^{-1} (C=O conjugated carbonyl group), 1593.47 cm^{-1} (C=C conjugated), 1562.76 cm^{-1} and 1350.11 (Asym and sym-NO_2).	^{1}H NMR: 8.578 (s, 1H, Ar-H,), 7.636-7.505 (m, 8H, Ar-H), 8.176 (d, 1H, ethylenic), 6.934 (d, 1H, furyl proton), 6.845 (d, 1H, furyl proton), 8.050 (d, 1H, ethylenic); ^{13}C NMR: 189.64 (C=O), 130.00, 128.49, (C=C), 153.50, 152.30 148.86, 138.06, 132.92, 131.42, 129.97, 129.81, 128.70, 122.78, 120.07, 119.13, 118.37, 110.20 (Ar-C).
13	2361.30 cm^{-1} (Aromatic ring) 1687.97 cm^{-1} (C=O acid), 1573.97 cm^{-1} (C=C conjugated), 1532.37 cm^{-1} (C=O aldehyde).	^{1}H NMR: 8.048 (d, 1H, Ar-H), 7.745-7.480 (m, 8H, Ar-H), 7.470 (d, 1H, ethylenic), 7.345 (d, 1H, ethylenic), 6.80 (d, 1H, furyl proton), 6.764 (d, 1H, furyl proton) ^{13}C NMR: 189.64 81 (C=O),131.89, 129.42 (C=C), 168.74 (C=O of acid), 151.72, 151.09, 134.40, 134.14, 130.97, 130.68, 129.87, 129.62, 124.88, 123.59, 110.32, 107.59 (Ar-C).
14	2340.06 cm^{-1} (Aromatic ring) 1658.29 cm^{-1} (C=O conjugated carbonyl group), 1584.37 cm^{-1} (C=C conjugated), 1342.49 (sym -NO_2), 1022.50 cm^{-1} (C-Br bond).	^{1}H NMR: 8.358 (d, 2H, Ar-H), 8.173 (d, 2H, Ar-H), 7.643 (d, 1H, Ar-H), 7.572 (d, 1H, Ar-H), 7.448 (d, 1H, Ar-H), 7.410 (d, 1H, ethylenic), 7.315 (d, 1H, ethylenic), 6.877 (d, 1H, furyl proton), 6.808 (d, 1H, furyl proton); ^{13}C NMR: 187.63(C=O), 131.69, 128.30 (C=C), 155.01, 150.90, 149.74, 142.39, 131.95, 131.15, 126.35, 123.83, 122.00, 120.88, 118.47, 110.14 (Ar-C).
15	2360.43 cm^{-1} (Aromatic ring) 1663.30 cm^{-1} (C=O conjugated carbonyl group), 1588.99 cm^{-1} (C=C conjugated), 1560.33 cm^{-1} and 1350.49 (Asym and sym -NO_2).	^{1}H NMR: 8.619 (d, 2H, Ar-H), 8.379 (d, 2H, Ar-H), 8.203 (d, 1H, Ar-H), 8.071 (d, 1H, Ar-H), 7.675 (d, 1H, Ar-H), 7.520 (d, 1H, Ar-H), 7.353 (d, 1H, ethylenic), 7.324 (d, 1H, ethylenic), 6.996 (d, 1H, furyl proton), 6.923 (d, 1H, furyl proton); ^{13}C NMR: 178.36 (C=O), 131.01, 124.87 (C=C), 155.47, 152.23, 148.57, 130.93, 130.70, 130.42, 129.75, 123.90, 123.06, 122.35, 120.62, 119.21, 118.66, 111.67, 110.83 (Ar-C).
16	1661.33 cm^{-1} (C=O conjugated carbonyl group), 1587.85 cm^{-1} (C=C conjugated) 1576.38 cm^{-1} and 1344.81 (Asym and sym -NO_2).	^{1}H NMR: 7.773 (d, 1H, Ar-H), 7.650 (d, 1H, Ar-H), 7.578 (d, 1H, Ar-H), 7.525 (d, 1H, Ar-H), 7.431 (d, 1H, ethylenic), 7.395 (d, 1H, ethylenic), 6.861 (d, 1H, furyl proton), 6.809 (d, 1H, furyl proton); ^{13}C NMR: 178.24 (C=O), 130.23, 124.42 (C=C), 154.90, 153.17, 147.14, 133.02, 132.51, 129.73, 129.08, 128.18, 123.95, 123.58, 122.99, 122.32, 119.75, 112.94, 112.30 (Ar-C).

Compound	IR (cm^{-1})	NMR data δ (ppm)
17	1656.05 cm^{-1} (C=O conjugated carbonyl group), 1587.51 cm^{-1} (C=C conjugated) 1568.26 cm^{-1} and 1343.40 (Asym and sym -NO_2), 1022.88 cm^{-1} (C-Cl bond).	^{1}H NMR: 8.371 (s, 1H, Ar-H,), 8.199 (d, 1H, Ar-H), 8.168 (d, 1H, Ar-H), 7.659 (d, 1H, Ar-H), 7.627 (d, 1H, Ar-H), 7.476 (d, 1H, Ar-H), 7.396 (d, 1H, Ar-H), 7.335 (d, 1H, Ar-H), 7.302 (d, 1H, ethylenic), 7.240 (d, 1H, ethylenic), 6.884 (d, 1H, furyl proton), 6.828 (d, 1H, furyl proton); ^{13}C NMR: 187.67 (C=O), 131.08, 128.48 (C=C), 154.44, 151.11, 149.74, 142.33, 133.95, 131.10, 130.86, 129.73, 123.89, 123.82, 123.00, 120.71, 118.77, 110.69 (Ar-C).
18	2339.23 cm^{-1} (Aromatic ring) 1656.80 cm^{-1} (C=O conjugated carbonyl group), 1585.20 cm^{-1} (C=C conjugated), 1549.97 cm^{-1} and 1341.45 (Asym and sym -NO_2), 1021.94 cm^{-1} (C-Cl bond).	^{1}H NMR: 8.360 (d, 2H, Ar-H), 8.175 (d, 2H, Ar-H), 7.711 (d, 4H, Ar-H), 7.449 (d, 1H, ethylenic), 7.406 (d, 1H, ethylenic), 6.881 (d, 1H, furyl proton), 6.796 (d, 1H, furyl proton); ^{13}C NMR: 187.61 (C=O), 131.20, 126.20 (C=C), 155.00, 150.91, 149.77, 142.40, 133.36, 129.75, 129.11, 128.97, 128.01, 125.22, 123.89, 121.00, 118.40, 110.15 (Ar-C).
19	2359.78 cm^{-1} (Aromatic ring) 1661.97 cm^{-1} (C=O conjugated carbonyl group), 1588.19 cm^{-1} (C=C conjugated), 1557.96 cm^{-1} and 1333.57 (Asym and sym -NO_2).	^{1}H NMR: 8.380-7.630 (m, 8H, Ar-H), 7.524 (d, 1H, ethylenic), 7.325 (d, 1H, ethylenic), 7.015 (d, 1H, furyl proton), 6.936 (d, 1H, furyl proton); ^{13}C NMR: 187.77 (C=O), 130.95, 125.19 (C=C), 153.64, 152.35, 149.84, 146.75, 142.25, 134.85, 129.79, 124.40, 123.89, 122.31, 122.66, 119.88, 113.21 (Ar-C).
20	2341.92 cm^{-1} (Aromatic ring) 1656.89 cm^{-1} (C=O conjugated carbonyl group), 1582.98 cm^{-1} (C=C conjugated) 1548.65 cm^{-1} and 1345.86 (Asym and sym -NO_2), 1024.07 cm^{-1} (C-Cl bond).	^{1}H NMR: 8.360 (d, 2H, Ar-H), 8.173 (d, 2H, Ar-H), 7.969 (d,1H,Ar-H), 7.943 (d, 1H, Ar-H), 7.493 (d, 1H, Ar-H), 7.467 (d, 1H, ethylenic), 7.410 (d, 1H, ethylenic), 7.258 (d, 1H, furyl proton), 6.923 (d, 1H, furyl proton); ^{13}C NMR: 187.77 (=O), 130.95, 127.38 (C=C), 152.14, 150.66, 149.79, 142.32, 131.13, 130.08, 129.76, 128.76, 127.73, 123.88, 119.22, 114.19 (Ar-C).
21	2357.71 cm^{-1} (Aromatic ring) 1661.58 cm^{-1} (C=O conjugated carbonyl group), 1586.90 cm^{-1} (C=C conjugated), 1094.27 cm^{-1} (C-Cl bond).	^{1}H NMR: 7.994-7.453 (m, 8H, Ar-H), 7.408 (d, 1H, ethylenic), 7.349 (d, 1H, ethylenic), 6.818 (d, 1H, furyl proton), 6.770 (d, 1H, furyl proton); ^{13}C NMR: 188.39 (C=O), 130.72, 128.27 (C=C) 155.45, 151.24,139.17, 136.55, 134.50, 129.83, 129.16, 128.94, 128.21, 125.71, 119.22, 118.35, 114.98, 108.69 (Ar-C).
22	2361.19 cm^{-1} (Aromatic ring) 1659.96 cm^{-1} (C=O conjugated carbonyl group), 1599.82 cm^{-1} (C=C conjugated), 1092.15cm^{-1} (C-Cl bond), 1518.53 cm^{-1} and 1357.69 (Asym and sym -NO_2).	^{1}H NMR: 7.982-7.431 (m, 8H, Ar-H), 7.402 (d, 1H, ethylenic), 7.319 (d, 1H, ethylenic), 6.801 (d, 1H, furyl proton), 6.782 (d, 1H, furyl proton); ^{13}C NMR: 188.15 (C=O), 131.91, 127.95 (C=C) 152.44, 150.54, 139.33, 136.33, 130.06, 129.89, 129.61, 129.30, 128.99, 128.95, 128.15, 123.99, 123.13, 119.68, 118.03, 112.32 (Ar-C).
23	2368.02 cm^{-1} (Aromatic ring) 1662.07 cm^{-1} (C=O conjugated carbonyl group), 1587.94 cm^{-1} (C=C conjugated) 1558.07 cm^{-1} and 1330.55 (Asym and sym -NO_2), 1107.92 cm^{-1} (C-Cl bond), 1028.14 cm^{-1} (C-Br bond).	^{1}H NMR: 7.953-7.365 (m, 8H, Ar-H), 7.340 d, 1H, ethylenic), 6.980 (d, 1H, ethylenic), 7.523 (d, 1H, furyl proton), 6.415 (d, 1H, furyl proton); ^{13}C NMR: 189.15(C=O), 130.70, 128.94 (C=C), 153.70, 151.28, 139.17, 135.45, 133.67, 132.09, 129.82, 125.93, 122.69, 119.20, 118.40, 108.78 (Ar-C).
24	2361.19 cm^{-1} (Aromatic ring) 1655.45 cm^{-1} (C=O conjugated carbonyl group), 1585.17 cm^{-1} (C=C conjugated), 1089.21 cm^{-1} (C-Cl bond), 1565.32 cm^{-1} and 1365.70 (Asym and sym -NO_2).	^{1}H NMR: 7.999-7.346 (m, 8H, Ar-H), 7.295 (d, 1H, ethylenic), 7.269 (d, 1H, ethylenic), 7.235 (d, 1H, furyl proton), 6.860 (d, 1H, furyl proton); ^{13}C NMR: 188.44 (C=O), 131.03, 127.05 (C=C), 152.75, 150.84, 139.19, 136.57, 130.96, 130.75, 129.85, 129.23, 128.95, 128.43, 128.31, 118.93, 118.78, 113.91 (Ar-C).
25	2362.03 cm^{-1} (Aromatic ring) 1665.37 cm^{-1} (C=O conjugated carbonyl group), 1603.77 cm^{-1} (C=C conjugated), 1091.96 cm^{-1} (C-Cl bond).	^{1}H NMR: 8.009-7.305 (m, 8H, Ar-H,), 7.283 (d, 1H, ethylenic), 7.139 (d, 1H, ethylenic), 6.820 (d, 1H, furyl proton), 6.799 (d, 1H, furyl proton); ^{13}C NMR: 187.40 (C=O), 130.26, 128.35 (C=C), 154.09, 151.24, 137.98, 136.14, 133.93, 131.17, 130.84, 130.30, 128.86, 123.82, 122.93, 119.94, 118.75, 110.52 (Ar-C).
26	2361.78 cm^{-1} (Aromatic ring) 1651.46 cm^{-1} (C=O conjugated carbonyl group), 1586.88 cm^{-1} (C=C conjugated), 1098.52 cm^{-1} (C-Cl bond), 2981.28 cm^{-1} (-OH bond)	^{1}H NMR: 7.894-7.241 (m, 6H, Ar-H), 7.369 (d, 1H, ethylenic), 7.340 (d, 1H, ethylenic), 7.225 (d, 1H, furyl proton), 6.843 (d, 1H, furyl proton); ^{13}C NMR: 187.32 (C=O), 129.44, 128.76 (C=C), 150.52, 149.41, 148.56, 137.86, 130.68, 130.47, 130.26, 129.91, 128.67, 126.74, 123.24, 122.71, 120.42, 117.66,110.13, 109.03 (Ar-C).
27	2361.88 cm^{-1} (Aromatic ring) 1659.89 cm^{-1} (C=O conjugated carbonyl group), 1595.91 cm^{-1} (C=C conjugated), 1072.98 cm^{-1} (C-Cl bond), 1555.77 cm^{-1} and 1350.49 (Asym and sym -NO_2).	^{1}H NMR: 8.582 (d, 1H, Ar-H), 8.190-7.463 (m, 7H, Ar-H,), 7.354 (d, 1H, ethylenic), 6.997 (d, 1H, ethylenic), 6.940 (d, 1H, furyl proton), 6.863 (d, 1H, furyl proton); ^{13}C NMR: 187.69 (C=O), 130.24, 127.25 (C=C), 153.29, 151.72, 148.56, 136.44, 131.86, 130.92, 130.74, 130.66, 130.43, 130.35, 123.89, 122.91, 119.84, 119.29, 118.58, 110.81 (Ar-C).
28	2360.00 cm^{-1} (Aromatic ring) 1648.68 cm^{-1} (C=O conjugated carbonyl group), 1585.81 cm^{-1} (C=C conjugated), 1028.40 cm^{-1} (C-Br bond).	^{1}H NMR: 7.914 (d, 1H, Ar-H), 7.651-7.406 (m, 6H, Ar-H), 7.241 (d, 1H, ethylenic), 6.817 (d, 1H, ethylenic), 6.782 (d, 1H, furyl proton), 6.600 (d, 1H, furyl proton) ^{13}C NMR: 187.54 (C=O), 130.38, 127.19(C=C), 154.68, 151.03, 136.51, 131.93, 131.84, 128.40, 126.30, 121.87, 120.16, 118.36, 110.00 (Ar-C).
29	2365.82 cm^{-1} (Aromatic ring) 1653.92 cm^{-1} (C=O conjugated carbonyl group), 1589.92 cm^{-1} (C=C conjugated), 1527.82 cm^{-1} and 1350.38 (Asym and sym -NO_2), 1090.65 cm^{-1} (C-Cl bond).	^{1}H NMR: 8.855 (s, 1H, Ar-H), 8.440 (d, 1H, Ar-H), 8.373 (d, 1H, Ar-H), 7.729 (t, 1H, Ar-H), 7.651 (d, 1H, Ar-H), 7.477 (d, 1H, Ar-H), 7.425 (d, 1H, Ar-H), 7.404 (d, 1H, Ar-H), 7.345 (d, 1H, ethylenic), 7.241 (d, 1H, ethylenic), 6.890 (d, 1H, furyl proton), 6.800 (d, 1H, furyl proton); ^{13}C NMR: 186.90 (C=O), 130.65, 127.22 (C=C), 154.98, 150.95, 148.21, 138.79, 134.63, 133.33, 131.20, 129.11, 128.97, 128.04, 126.20, 125.22, 122.64, 120.87, 110.12, 109.11 (Ar-C).
30	2360.97 cm^{-1} (Aromatic ring) 1662.66 cm^{-1} (C=O conjugated carbonyl group), 1592.11 cm^{-1} (C=C conjugated), 1573.89 cm^{-1} and 1353.27 (Asym and sym -NO_2).	^{1}H NMR: 8.838-7.651 (m, 8H, Ar-H), 7.616 (d, 1H, ethylenic), 7.593 (d, 1H, ethylenic), 7.535 (d, 1H, furyl proton), 6.989 (d, 1H, furyl proton); ^{13}C NMR: 186.85 (C=O), 130.96, 127.31 (C=C), 151.88, 150.56, 148.16, 147.15, 138.59, 134.27, 132.48, 130.72, 130.21, 129.03, 123.94, 122.58, 121.59, 119.61, 118.95, 112.96 (Ar-C).

FTIR analysis: Assignment of selected characteristics IR bands provides significant indication for the formation of chalcones and starting arylfurfurals. In the stating material arylfurfural (C=O) and (C-H) absorbed in the expected region; (C=O) in the 1610-1681 cm^{-1} and (C-H) stretch of aldehydes show a weak band in the 2863-2846 cm^{-1}, while in the chalcones (C-H) stretching band is absent and (C=O) band shifted to lower wave numbers due to conjugated carbonyl bond and also show absorption band (CH=CH) in the 1600-1586 cm^{-1} region which also confirms the formation of chalcones.

^{1}H NMR analysis: The ^{1}H NMR spectra (300 MHz, $CDCl_3$) of the staring arylfurfurals show characterstic singlet peak between δ 9.64-9.72 ppm and two doublet at δ 6.78-6.98 and δ 7.29-7.96 ppm. The protons belonging to the aromatic ring were observed with the expected chemical shift.

^{13}C NMR analysis: Finally, ^{13}C NMR (75 MHz, $CDCl_3$) spectra of all compounds were recorded and spectral signals are in good agreement with the probable structure. Carbon of C=O displayed signal at δ 177.21-177.72 ppm in the arylfurfurals while in the chalcones C=O carbon displayed signal at δ 186.65-198.02 ppm and CH=CH shows a singlet at δ 121 and δ 137 ppm respectively.

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