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Synthesis and antimicrobial activity of some novel 5- and 6-substituted furocoumarins

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5-Hydroxybergapten **1a** and 5-hydroxyisopimpinellin **1b** react with bromine and hydrated aluminium nitrate to give 5-hydroxy-6-bromobergapten **2a**, 5-hydroxy-6-bromoisopimpinellin **2b**, 5-hydroxy-6-nitrobergapten **2c** and 5-hydroxy-6-nitroisopimpinellin **2d.** While the reaction of **1a** and **1b** with ammonium acetate and sodium acetate yield 5-aminobergapten **3a**, 5- aminoisopimpinellin **3b**, 5-acetoxybergapten **3c** and 5-acetoxyisopimpinellin **3d.** The treatment of **1a** and **1b** with ethyl bromoacetate and allyl bromide affords 5-ethyl acetatoxybergapten **3i**, 5-ethyl acetatoxyisopimpinellin **3j**, 5- allyloxybergapten **4a** and 5-allyloxyisopimpinellin **4b**. Also, 5- hydrazidobergapten **3g,** 5-hydrazidoisopimpinellin **3h**, 5-azidobergapten **3m** and 5-azidoisopimpinellin **3n** are prepared through 5-ethylcarboxy bergapten **3e**, 5-ethylcarboxy isopimpinellin **3f**, 5-acetanilido sulphonyloxy bergapten **3k** and 5-acetanilido sulphonyloxy isopimpinellin **3l**. Claisen rearrangement of **4a-b** afford 6-allyl-5-hydroxybergapten **5a** and 6-allyl-5-hydroxy-isopimpinellin **5b**.

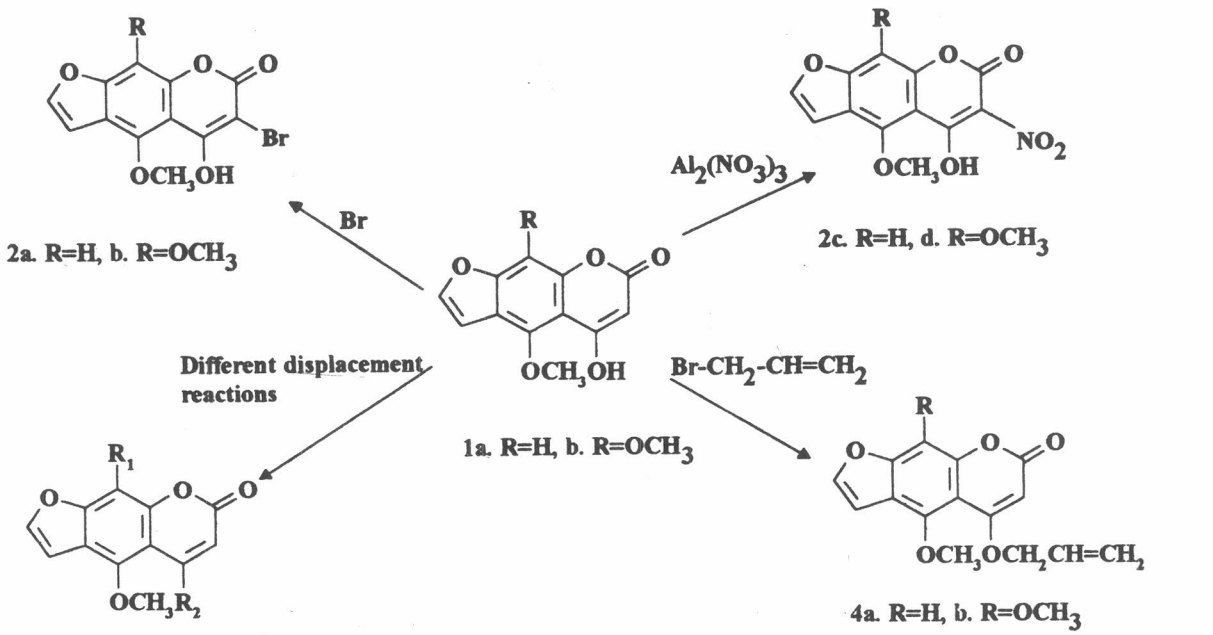
5-Hydroxybergapten **1a** and 5-hydroxyisopimpinellin **1b** are furocoumarin compounds which are known to possess pronounced photosensitizing[1-3], antibacterial [4], tuberculostatic[5] and molluscicidal[6] activities. Since, **1a** and **1b** appeared to be potential key compounds, they were subjected to bromination, nitration, amination, acetylation and allylation reactions alongside their treatment with ethyl chloroformate, ethyl bromoacetate and *p*-acetanilide sulphonyl chloride.

Results and Discussion

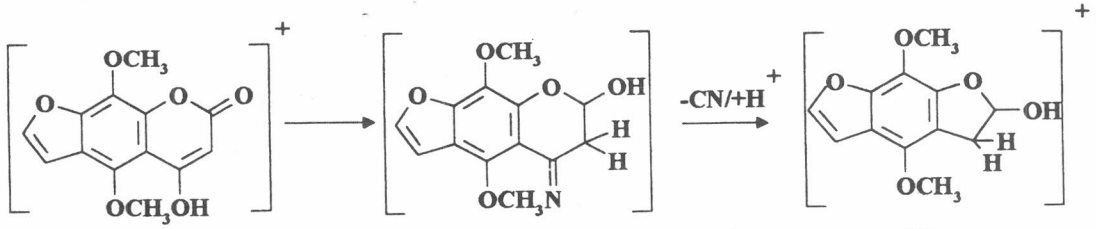
Bromination of bergapten and isopimpinellin using bromine in chloroform afforded 2,3,9-tribromobergapten and 6-bromoisopimpinellin[7], respectively. While, bromination of other parent furocoumarins gave their 4-bromo derivatives[8,9]. 6-Bromo products could be obtained only upon bromination of the dihydro derivatives of isopimpinellin, bergapten and their congeners[10,11]. The behaviour of 5-hydroxyfurocoumarins towards bromination reaction was similar to that of 2,3-dihydrofurocoumarin analogues. Thus, treatment of **1a** and **1b** with bromine in chloroform yielded the corresponding 6-bromo derivatives **2a** and **2b** (Table I). The UV of **2a** and **2b** revealed the expected maxima of substituted furocoumarins. Their mass spectra showed the molecular ions (M^+) at m/z 310/312 (6.1/5.9%) and 340/342 (11.4/11.8%), respectively.

Nitration of dihydrocoumarins[7,10,11] with nitric acid in glacial acetic acid have been reported to give 6-nitro derivatives. However, nitration of parent furocoumarins[8,12] with nitric acid in acetone afforded 4-nitro derivatives. Attempts to nitrate **1a** and **1b** either by nitric acid in glacial acetic acid or in acetone were fruitless. So, trials were made to approach other nitrating reagents. Success was met with a modified method previously followed for the nitration of tetralin[13] which is not an aromatized heterocyclic compound. Thus, treatment of **1a** and **1b** with hydrated aluminium nitrate[13] in absolute ethanol gave 6-nitro derivatives **2c** and **2d** (Table I). The mass spectra of **2c** and **2d** revealed the molecular ions (M^+) at m/z 277 (18.8%) and 307 (5.6%), respectively. The ^{1}H NMR spectrum of **2c** showed the absence of H-6 due to the introduction of NO_2 group at 6-position as previously reported in dihydro-furocoumarin analogues[7,8,10-12].

Reduction of 4-nitroxanthotoxin with tin and stannous chloride[8] in acidified alcohol or with



3a. R_1=H , R_2=NH_2
b. R_1=OCH_3, R_2=NH_2
c. R_1=H , R_2=$OCOCH_3$
d. R_1=OCH_3, R_2=$OCOCH_3$
e. R_1=H , R_2=OCOOEt
f. R_1=OCH_3 , R_2=OCOOEt
g. R_1=H , R_2=$OCONHNH_2$
h. R_1=OCH_3 , R_2=$OCONHNH_2$
i. R_1=H , R_2=OCH_2COOEt
j. R_1=OCH_3 , R_2=OCH_2COOEt
k. R_1=H , R_2=OSO_2Ph-$NHCOCH_3$-p
l. R_1=OCH_3 , R_2=OSO_2Ph-$NHCOCH_3$-p
m. R_1=H , R_2=N_3
n. R_1=OCH_3, R_2=N_3



palladized charcoal[8] afforded 4-amino derivative. However, reduction of 9-nitrobergapten gave 9-aminobergapten.

The nuclear amination of **1a** and **1b** could be achieved upon treatment with ammonium acetate in glacial acetic acid to afford the corresponding 5-amino derivatives **3a** and **3b** (Table I). The mass spectrum of **3b** revealed its M^+ at m/z 261 (61%). The base peak A at m/z 236 (100%) is probably resulted from M^+ ion by the loss of cyano group with hydrogen ion transfer *via* rearranged transition ions, which is uncommon event in

Table I—Antimicrobial activity of compounds **1-5**

Compd	*C. albicans*	*S. aureus*	*E. coli*	*B. subtilis*	*A. niger*	*S. cervisiae*
1a	+++	+++	+++	+++	+++	+++
1b	+++	++	+++	++	++	++
2a	+	+	–	+	–	–
2b	–	+	–	+	–	+
2c	+++	+++	+++	++	++	+++
2d	+++	+	++	+	+	–
3a	–	–	++	–	+	–
3b	–	–	++	++	–	+
3c	+++	+	–	+	+	–
3d	–	+	–	–	–	++
3e	–	+++	+++	–	–	–
3f	–	–	+++	++	+	–
3g	++	+	+++	–	+++	+
3h	+++	++	++	–	++	++
3i	–	–	–	–	–	–
3j	–	++	–	–	–	++
3k	-	++	+++	++	++	-
3l	-	+++	+++	+++	++	-
3m	+	-	+	-	-	-
3n	-	-	-	-	-	-
4a	++	-	-	-	+	-
4b	+	+	-	-	-	-
5a	-	-	+	+	-	-
5b	-	-	++	+	+	-

nitrogenous compounds[14]. ^{1}H NMR spectra of **3a** showed two singlets at 2.71 and 6.70 ppm attributed to NH_2 group and the hydrogen at C-6, respectively.

Earlier acetylation[15] of **1a** by two moles of acetyl chloride have been reported to give 3-acetyl-4-hydroxy-5-acetoxypsoralene. While, acetylation[15] of **1b** gave either the diacetyl analogue or a triacetyl derivative depending on the molar ratio of the acetyl chloride used. Whereas, in the present study acetylation of **1a** and **1b** by freshly prepared fused sodium acetate in acetic anhydride afforded 5-acetoxy derivatives **3c** and **3d** (Table I). Their mass spectra showed the molecular ions (M^+) at m/z 274 (37.8%) and 304 (59.2%), respectively.

The reaction of **1a** and **1b** with ethyl chloroformate afforded 5-ethyl carboxy derivatives 3e and 3f. Their structures were confirmed from their reaction with hydrazine hydrate to afford the corresponding hydrazide derivatives **3g** and **3h** (Table I). The MS of **3g** showed its M^+ at 290 (1.3%) which suffered from the loss of methyl radical with hydrogen ion transfer to afford the base peak at m/z 276 (100%).

The reaction of **1a** and **1b** with ethyl bromoacetate yielded 5-ethyl acetoxy derivatives **3i** and **3j** (Table I). The ^{1}H NMR of **3j** showed the existence of ethyl acetoxy group, since the ethyl appeared as a triplet at 1.26 ppm (methyl group) and as a quartet at 4.24 ppm (methylene group). The CH_2 of acetoxy group appeared as a singlet at 5.09 ppm.

Treatment of **1a** and **1b** with *p*-acetanilide sulphonyl chloride afforded *p*-acetanilide sulphonyloxy derivatives **3k** and **3l.** Their IR spectra showed the characteristic bands for SO_2 at 1360 and 1175 cm^{-1} for **3k** and at 1362 and 1175 cm^{-1} for **3l**. The formation of **3k** and **3l** was further confirmed from their reaction with sodium azide to give 5-azido derivatives **3m** and **3n** (Table I).

Reaction of **1a** and **1b** with allyl bromide afforded 5-allyloxy derivatives **4a** and **4b**. The ^{1}H NMR of **4b** showed the presence of allyloxy group and of H-6 at 5.60 ppm. Claisen rearrangement of **4a** and **4b** with N,N-diethylaniline[16] gave 6-allyl-5-hydroxy derivatives **5a** and **5b** (Table I). The IR spectrum of **5a** showed an absorption band at 3270 cm^{-1} due to OH group and ^{1}H NMR of **5b** showed the peak at 10.01 ppm due to –OH group.

Antimicrobial activity

The antimicrobial activity of all the synthesized compounds were tested against *Bacillus subtilis*

and *Staphylococcus aureus* (gram +ve), *Escherichia coli* and *Salmonella typhi* (gram –ve) bacteria and against pathogenic fungi, *Aspergillus niger* and two species of yeast such as *Candida albicans* and *Saccharomyces cervisiae* using the strip plate agar technique[17]. Such assay indicated that none of the compounds had an activity against *Salmonella typhi*. The results are summarised in Table I. It shows that the introduction of bromo group at position- 6 in **1a** and **1b** in compounds **2a** and **2b** caused inactivation, while nitration showed somewhat a similar activity as the starting materials **1a** and **1b.** Compounds **3c** and **3h** showed high activity towards *Candida albicans*, while compounds **3g, 4a** and **5b** showed a moderate activity against the same organism. Furthermore, the compounds **3e** and **3f** with ethyl carboxy group, compounds **3g** and **3h** with hydrazino carboxy and compounds **3k** and **3l** with *p*-acetanilide sulphonyloxy group at position -5 showed high activity against gram negative bacteria (*Escherichia coli*).

Experimental Section

Melting points are uncorrected. The UV spectra were recorded in methanol on a Shimadzu UV-visible recording Spectrophotometer UV- 240 Graphicord; IR spectra in KBr on a Shimadzu CVT- 04; ^{1}H NMR on Bruker AM-200 with $CDCl_3$ or DMSO-d_6 as solvent (chemical shifts in δ, ppm) using TMS as internal reference and the mass spectra on a Varian MAT CH-5 and CH-7 at 70 ev.

Preparation of 5-hydroxy-6-bromofurocoumarins 2a, b. A mixture of **1a/1b** (0.01 moles) in chloroform (150 mL) and bromine (0.01 moles) in chloroform (10 mL) was heated on a water-bath for 1.5 hr. The reaction mixture was evaporated *in vacuo* and the solid obtained was crystallized from acetic acid to give a pale yellow needles of **2a/2b**.

4-Methoxy-5-hydroxy-6-bromo-7H-furo[3,2-g][1]-benzopyran-7-one 2a: m.p. >300°C, yield 67%, UV (λ_{max}): 205, 231, 267, 314 nm; MS: m/z (%), 310/312 (M^+, 6.2/5.9), 309/311 (25.4/27.0), 268/270 (4.5/4.1), 267/269 (3.3/3.4), 232 (13.3), 203 (3.5), 190 (100), 175 (17.7), 147 (20.5). Anal. Calcd for $C_{12}H_7BrO_5$ (311): C, 46.30; H, 2.25; Br, 25.72, Found: C, 46.56; H, 2.23; Br, 26.00%.

4, 9-Dimethoxy-5-hydroxy-6-bromo-7H-furo[3,2-g][1]benzopyran-7-one 2b: m.p. >300°C, yield 66%, UV (λ_{max}): 205, 232, 270, 312 nm; MS: m/z (%), 340/342 (M^+, 11.5/11.9), 325/327 (3.8/3.5), 262 (17.1), 231 (5.2), 220 (100), 205 (13.7), 177 (7.8), 149 (52.4). Anal. Calcd for $C_{13}H_9BrO_6$ (341): C, 45.74; H, 2.63; Br, 23.46, Found: C, 45.38; H, 2.52; Br, 23.60%.

Preparation of 5-hydroxy-6-nitrofurocoumarins 2c, d. A mixture of **1a/1b** (0.01 moles) and agitated aluminium nitrate in ethanol (10 mL) was heated on a water-bath for 3 hr. The yellow solution was evaporated till dryness and the residue washed with water. The residue was crystallized from ethanol to give pale yellow crystals of **2c/2d**.

4-Methoxy-5-hydroxy-6-nitro-7H-furo[3, 2-g][1]-benzopyran-7-one 2c: m.p. 170°C, yield 68%, MS: m/z (%), 277(M^+,18.8), 259 (12.3), 247 (11.6), 232 (9.4), 217 (11.8), 204 (14.8), 204 (14.8), 190 (100), 175 (34.4), 147 (47.3), 119 (13.3); ^{1}H NMR: 7.95 (d, H-2, *J*=2.8 Hz), 7.11 (d, H-3, *J*=2.8 Hz), 7.18 (s, H-9), 3.98 (s, OCH_3-4). Anal. Calcd for $C_{12}H_7NO_7$ (277): C, 51.98; H, 2.52; N, 5.05, Found: C, 52.00; H, 2.65; N, 5.12%.

4,9-Dimethoxy-5-hydroxy-6-nitro-7H-furo[3, 2-g]-[1]benzopyran-7-one 2d: m.p. 178°C, yield 66%, MS: m/z (%), 307 (M^+, 5.6), 306 (21.5), 277 (16.1), 262 (17.4), 247 (18.2), 234 (15.7), 220 (89.5), 219 (22.6), 205 (100), 177 (72.7), 163 (23.3). Anal. Calcd for $C_{13}H_9NO_8$ (307): C, 50.81; H, 2.93; N, 4.56, Found: C, 50.68; H, 3.00; N, 4.75 %.

Preparation of 5-aminofurocoumarins 3a, b. A mixture of **1a/1b** (0.01 moles) in glacial acetic acid (10 mL) and ammonium acetate (0.1 moles) was heated on a water-bath for two days. The mixture was poured onto ice, then allowed to stand at 5-10°C for 3 hr. The deposited product was filtered and crystallized from chloroform to give pale yellow needles of **3a/3b**.

4-Methoxy-5-amino-7H-furo[3,2-g][1]benzopyran-7-one 3a: m.p. 130°C, yield 30%, UV (λ_{max}): 205, 243, 261sh, 312 nm; ^{1}H NMR: 7.43 (d, H-2, *J*=2.6 Hz), 7.19 (s, H-9), 6.87 (d, H-3, *J*=2.6 Hz), 6.70 (s, H-6), 4.18 (s, OCH_3-4), 2.71 (s, NH_2). Anal. Calcd for $C_{12}H_9NO_4$ (231): C, 62.33; H, 3.89; N, 6.06, Found: C, 62.06; H, 3.75: N, 6.00 %.

4, 9-Dimethoxy-5-amino-7H-furo[3, 2-g][1]benzopyran-7-one 3b: m.p 90°C, yield 36%, UV (λ_{max}): 203, 240, 262sh, 309 nm; MS: m/z (%), 261 (M^+, 61.0), 246 (25.9), 236 (100), 221 (28.3), 203 (10.8), 191 (4.4), 175 (7.0), 163 (4.4). Anal. Calcd

for $C_{13}H_{11}NO_5$ (261): C, 59.77; H, 4.21; N, 5.36, Found: C, 59.95; H, 4.35; N, 5.03%.

Preparation of 5-acetoxyfurocoumarins 3c, d. A mixture of **1a/1b** (0.01 moles) and freshly prepared fused sodium acetate (0.01 moles) in acetic anhydride (10 mL) was heated on a water bath for 1.5 hr. The mixture was left to stand at room temperature till the product precipitated out. The precipitate was filtered and recrystallized from acetic acid to give yellow needles of **3c/3d**.

4-Methoxy-5-acetoxy-7H-furo[3, 2-g][1]benzopyran-7-one 3c: m.p. 167°C, yield 66%, MS: m/z (%), 274 (M^+, 37.9), 259 (6.5), 245 (8.9), 232 (38.0), 204 (4.1), 203 (4.4), 190 (100), 175 (17.0), 147 (23.4); ^{1}H NMR: 7.60 (d, H-2, J=2.6 Hz), 7.24 (s, H-9), 6.95 (d, H-3, J=2.6 Hz), 6.02 (s, H-6), 4.14 (s, OCH_3-4), 2.38 (s, $COCH_3$-5). Anal. Calcd for $C_{14}H_{10}O_6$ (274): C, 61.31; H, 3.64, Found: C, 61.12; H, 3.80%.

4,9-Dimethoxy-5-acetoxy-7H-furo[3,2-g][1]benzopyran-7-one 3d: m.p. 187°C, yield 65%, MS: m/z (%), 304 (M^+,59.2), 275 (12.6), 262 (35.2), 247 (2.9), 220 (100), 205 (84.8), 191 (11.4), 177 (36.9). Anal. Calcd for $C_{15}H_{12}O_7$ (304): C, 59.21; H, 3.94, Found: C, 59.10; H, 4.00%.

Preparation of 5-ethylcarboxyfurocoumarins 3e, f. A solution of **1a/1b** (0.01 moles) in dry acetone (150 mL) was treated with ethyl chloroformate (0.01 moles) in the presence of anhydrous potassium carbonate. The mixture was heated for 3 hr, then filtered while hot and evaporated till dryness to give a white substance which was recrystallized from acetone to give **3e/3f.**

4-Methoxy- 5-ethylcarboxy - 7H-furo[3, 2-g][1]-benzopyran-7-one 3e: m.p. 120°C, yield 70%, Anal. Calcd for $C_{15}H_{12}O_7$ (304): C, 59.21; H, 3.94, Found: C, 59.11; H, 3.96 %.

4, 9-Dimethoxy-5-ethylcarboxy-7H-furo[3,2-g]-[1]benzopyran-7-one 3f: m.p. 130°C, yield 80%, Anal. Calcd for $C_{16}H_{14}O_8$ (334): C, 57.48; H, 4.19, Found: C, 57.80; H, 3.99 %.

Preparation of furocoumarinyloxy hydrazides 3g, h. Compounds **3e/3f** (0.01 moles) was dissolved in absolute ethanol (80 mL) and the hydrazine hydrate (0.05 moles) was added dropwise during 10 min, while maintaining the temperature at 60°C. The reaction mixture was left at room temperature and the corresponding hydrazide derivatives were recrystallized from ethanol to give white needles of **3g/3h.**

4-Methoxy -5-(hydrazino)carboxy-7H-furo[3, 2-g][1]benzopyran-7-one 3g: m.p. 168°C, yield 62%, MS: m/z (%), 290 (M^+, 1.3), 276 (100), 261 (54.9), 233 (9.7), 232 (5.3), 218 (18.4), 190 (8.8). Anal. Calcd for $C_{13}H_{10}N_2O_6$ (290): C, 53.79; H, 3.44; N, 9.65, Found: C, 54.00; H, 3.28; N, 9.44 %.

4,9-Dimethoxy-5-(hydrazino)carboxy-7H-furo-[3,2-g][1]benzopyran-7-one 3h: m.p. 144°C, yield 59%, Anal. Calcd for $C_{14}H_{12}N_2O_7$ (320): C, 52.50; H, 3.75; N, 8.75, Found: C, 52.52; H, 3.59; N, 8.67%.

Preparation of 5-ethylacetatoxyfurocoumarins 3i, j. A mixture of **1a/1b** (0.01 moles), ethyl bromoacetate (0.01 moles) in dry acetone (140 mL) in the presence of anhydrous potassium carbonate was heated on a water-bath for 15 hr. The reaction mixture was filtered while hot and the solvent distilled off. The residue was recrystallized from acetone to give white needles of **3i/3j.**

4-Methoxy-5-ethylacetatoxy-7H-furo[3,2-g][1]-benzopyran-7-one 3i: m.p. 120°C, yield 52 %, UV ($\lambda_{max.}$): 205, 232, 252sh, 260, 296 nm. Anal. Calcd for $C_{16}H_{14}O_7$ (318): C, 60.37; H, 4.40, Found: C, 60.40; H, 4.29%.

4,9-Dimethoxy-5-ethylacetatoxy-7H-furo[3,2-g]-[1]benzopyran-7-one 3j: m.p. 133°C, yield 61%, MS: m/z (%), 348 (M^+, 100), 333 (32.3), 318 (2.3), 275 (3.0), 260 (7.3), 247 (5.3), 245 (8.8), 229 (15.1), 205 (13.8), 177 (11.7); ^{1}H NMR: 8.13 (d, H-2, J=2.4 Hz), 7.23 (d, H-3, J=2.4 Hz), 5.82 (s, H-6), 5.09 (s, CH_2-1′), 4.24 (q, CH_2-2′, J=14 Hz), 4.07 (s, OCH_3-4), 3.95 (s, OCH_3-9), 1.26 (t, CH_3, J=6 Hz). Anal. Calcd for $C_{17}H_{16}O_8$ (348): C, 58.62; H, 4.59, Found: C, 58.40; H, 4.87%.

Preparation of 5-(*p*-acetanilido)sulphonyloxy-furocoumarins 3k, l. To a solution of **1a/1b** (0.01 moles) in dry acetone (140 mL) in the presence of anhydrous potassium carbonate (0.01 moles), *p*-acetanilide sulphonyl chloride (0.01 moles) was added. The reaction mixture was heated for 9 hr, then filtered while hot and the solvent distilled off. The residue was recrystallized from acetone to give **3k/3l.**

4-Methoxy-5-(p-acetanilido)sulphonyloxy-7H-furo-[3,2-g][1]-7-one 3k: m.p. 218°C, yield 70%, IR: 3464, 3275 (NH), 1722 (C=O), 1664, 1615, 1580, 1520 (C=C, aromatic), 1360, 1175 (SO_2), 1280 (C-N), 1245 (C-O) cm^{-1}. Anal. Calcd for $C_{20}H_{15}NO_8S$

(429): C, 55.94; H, 3.49; N, 3.26; S, 7.45, Found: C, 55.65; H, 3.58; N, 3.00; S, 7.68%.

4, 9-Dimethoxy-5-(p-acetanilido)sulphonyloxy-7H-furo[3,2-g][1]-7-one 3l: m.p. 210°C, yield 65%, IR: 3422, 3319 (NH), 1705 (C=O), 1589, 1515, 1490 (C=C, aromatic), 1362, 1175 (SO_2), 1275 (C-N), 1244 (C-O) cm^{-1}. Anal. Calcd for $C_{21}H_{17}NO_9S$ (459): C, 54.91; H, 3.70; N, 3.05; S, 6.97, Found: C, 54.84; H, 3.62; N, 3.12; S, 7.00%.

Preparation of 5-azidofurocoumarins 3m, n. To a solution of **3k/3l** (0.01 moles) in dimethyl formamide (8 mL) was added sodium azide (0.01 moles) portionwise while stirring at room temperature during 30 min. The mixture was allowed to stand at room temperature for 3 hr, then poured onto ice to afford pink precipitate. The precipitate was recrystallized from acetone to give pink crystals of **3m/3n**.

4-Methoxy-5-azido-7H-furo[3, 2-g][1]benzopyran-7-one 3m: m.p. 130°C, yield 71%, MS: m/z (%), 257 (M^+, 100), 229 (32.4), 215 (5.3), 214 (39.9), 200 (18.8), 174 (6.0), 158 (9.5), 144 (11.0), 118 (4.6), 116 (6.2). Anal. Calcd for $C_{12}H_7N_3O_4$ (257):C, 56.03; H, 2.72; N, 16.34, Found: C, 56.00; H, 2.85; N, 16.32%.

4, 9-Dimethoxy-5-azido-7H-furo[3, 2-g][1]benzopyran-7-one 3n: m.p. 117°C, yield 65%, Anal. Calcd for $C_{13}H_9N_3O_5$ (287): C, 54.17; H, 3.13; N, 14.63, Found: C, 45.00; H, 3.20; N, 14.70%.

Preparation of 5-allyloxyfurocoumarins 4a, b. A mixture of **1a/1b** (0.01 moles) and allyl bromide (0.1 moles) in acetone (140 mL) in the presence of anhydrous potassium carbonate (0.01 moles) was heated for 15 hr. The reaction mixture was filtered immediately while hot and the solvent distilled off to give a brown residue. The products **4a/4b** were recrystallized from chloroform as white needles.

4-Methoxy- 5 -allyloxy-7H-furo[3, 2-g][1]benzopyran-7-one 4a: m.p. 138°C, yield 75%, MS: m/z (%), 272 (M^+, 95.0), 257 (33.4), 243 (15.7), 232 (2.5), 231 (8.3), 203 (20.3), 190 (100), 175 (15.2), 147 (13.5). Anal. Calcd for $C_{15}H_{12}O_5$ (272): C, 66.17; H, 4.41, Found: C, 66.30; H, 4.53%.

4, 9-Dimethoxy-5-allyloxy-7H-furo[3, 2-g][1]-benzopyran-7-one 4b: m.p. 98°C, yield 75%, MS: m/z (%), 302 (M^+, 90.3), 288 (2.7), 287 (12.7), 273 (4.2), 245 (2.8), 233 (44.8), 220 (100), 205 (27.8); ^1H NMR: 7.60 (d, H-2, J=2.6 Hz), 6.90 (d, H-3, J=2.6 Hz), 6.09 (m, H-2'), 5.60 (s, H-6), 5.47 (dd, CH_2-3'), 4.65 (s, CH_2-1'), 4.16 (s, OCH_3-4), 3.90 (s, OCH_3-9). Anal. Calcd for $C_{16}H_{14}O_6$ (302): C, 63.35; H, 4.63, Found: C, 63.60; H, 4.71%.

Preparation of 5-hydroxy-6-allylfurocoumarins 5a, b. A mixture of **4a/4b** (0.01 moles) and N,N-diethylaniline (50 mL) was heated for 12-15 hr. The mixture was kept to stand at room temperature for two days, then dissolved in chloroform and extracted with 5% aqueous solution of sodium carbonate. The aqueous solution was acidified with 10% hydrochloric acid to yield buff precipitate of **5a/5b** which was filtered and recrystallized from chloroform.

4-Methoxy-5-hydroxy- 6 -allyl-7H-furo[3, 2-g]-[1]benzopyran-7-one 5a: m.p. 168°C, yield 48%, IR: 3270 (OH), 1690 (C=O), 1635, 1580, 1495 (C=C, aromatic), 1280 (C-O) cm^{-1}. Anal. Calcd for $C_{15}H_{12}O_5$ (272): C, 66.17; H, 4.41, Found: C, 65.98; H, 4.38%.

4,9-Dimethoxy-5-hydroxy-6-allyl-7H-furo[3, 2-g][1]benzopyran-7-one 5b: m.p. 107°C, yield 39%, ^1H NMR: 10.01 (s, OH), 7.64 (d, H-2, J=2.4 Hz), 7.23 (d, H-3, J=2.4 Hz), 5.97 (m, H-2'), 5.10 (m, CH_2-3'), 4.36 (s, OCH_3-4), 4.23 (s, OCH_3-9), 3.33 (d, CH_2-1', J=6.2 Hz). Anal. Calcd for $C_{16}H_{14}O_6$ (302): C, 63.35; H, 4.63, Found: C, 63.39; H, 4.60%.

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