

# Synthesis and Reactions of Some New Hydroxymethylene Spirofurobenzopyran Derivatives

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Claisen condensation of furochromanone derivatives with ethyl formate yielded 6-(hydroxymethylene)furobenzopyran derivatives; these with hydrazine hydrate, phenylhydrazine, hydroxylammonium chloride, malononitrile, and ethyl cyanoacetate afforded furopyrazolobenzopyran, furoisoxazolobenzopyran, and furopyranobenzopyran derivatives.

Condensation reaction of furobenzopyran-6-carbaldehyde derivatives with indan-1,3-dione gave furobenzopyran-ylmethyleindan-1,3-dione derivatives which gave indanopyridine derivatives on treatment with ammonia. Moreover, condensation reaction with dimedone, pyrazolone, barbituric acid, and thiobarbituric acid yielded oxanthenylfurobenzopyran derivatives, furobenzopyran-ylmethylenepyrazolones, and furobenzopyran-ylmethylenobarbituric resp. -thiobarbituric acid.

Furobenzopyran derivatives occupy a position of considerable significance as a result of their widespread occurrence in plants and their potential as important pharmaceuticals [1]. It is well-known that some furobenzopyran derivatives possess coronary vasodilating activity [2, 3]. Several substituted furobenzopyrans show potent spasmolytic activity [4, 5]. Recently, furobenzopyran derivatives (the essential constituent of Ammi Visnaga) exhibited some effects for example decreasing the atherogenic VLDL + LDL cholesterol fraction and elevating antiatherogenic HDL cholesterol fraction [6–8]. Furobenzopyran derivatives produced also crosslinks in photoreaction with DNA [9].

Thus, the high pharmacological importance of furobenzopyran derivatives prompted us to investigate the synthesis of some new derivatives of expected biological activity.

The naturally occurring furobenzopyrones *visnagin* and *khellin* yielded *visnaginone* and *khellinone* upon hydrolysis with alcoholic potassium hydroxide solution [10, 11].

Spirocyclization of *visnaginone* and *khellinone* with cyclohexanone afforded the corresponding 4-methoxy/4,9-dimethoxy-7-pentamethylene-5*H*-furo[3,2-*g*][1]chroman-5-ones (*Ia*, *Ib*) [12].

Claisen condensation of *Ia*, *Ib* with ethyl formate in the presence of sodium metal yielded 6-hydroxymethylene-4-methoxy/4,9-dimethoxy-7-pentamethylene-7*H*-furo[3,2-*g*][1]benzopyran-5-one (*IIa*, *IIb*, see Scheme 1).

The spectral data were compatible with the assigned structures. The infrared spectra showed bands at 1655 cm<sup>-1</sup> and 3354 cm<sup>-1</sup> for C=O and OH groups, respectively.

Refluxing *IIa*, *IIb* with hydrazine hydrate or phenylhydrazine afforded 3-methoxy/3,7-dimethoxy-9-pentamethylene-9*H*-furo[3,2-*g*]pyrazolo[4,3-*c*][1]benzopyran (*IIIa–IIIc*).

Structures *IIIa–IIIc* were supported by elemental analysis and spectral data. Their infrared spectra showed the absence of chromanone moiety and revealed absorption band at 1618–1620 cm<sup>-1</sup> for C=N. The <sup>1</sup>H NMR (CDCl<sub>3</sub>) spectrum of *IIIc* showed signals at  $\delta$ : 1.5–2.3 (m, 10H, 5CH<sub>2</sub>), 3.7 (s, 3H, OCH<sub>3</sub>), 6.7 (s, 1H, H-7), 6.9 (d, 1H, *J* = 2 Hz, furan H-3), 7.00–7.30 (m, 5H, H<sub>arom</sub>), 7.5 (d, 1H, *J* = 2 Hz, furan H-2), and 7.9 (s, 1H, pyrazole H-5).

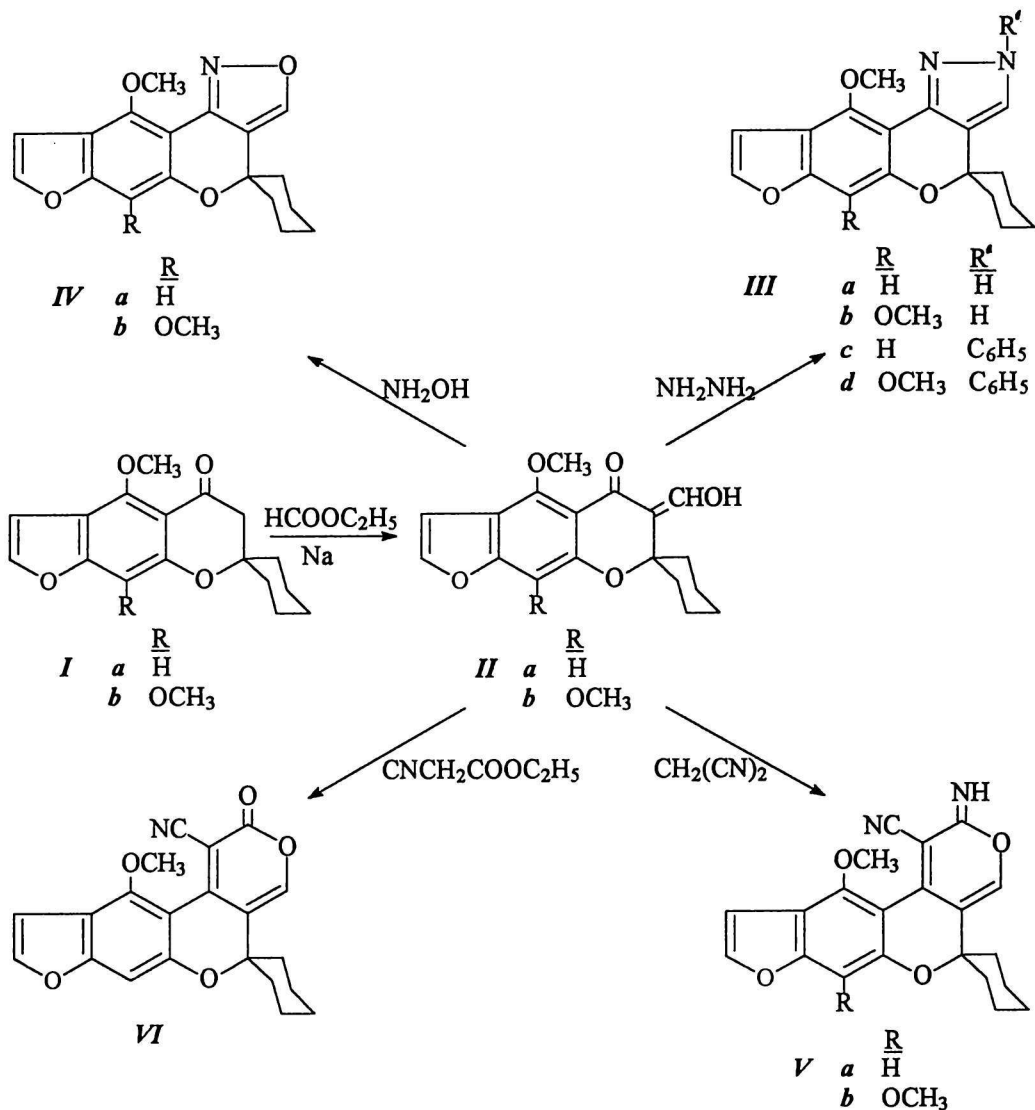
Moreover, the reaction of *IIa*, *IIb* with hydroxylammonium chloride gave 3-methoxy/3,7-dimethoxy-9-pentamethylene-9*H*-furo[3,2-*g*]isoxazolo[4,3-*c*][1]benzopyran (*IVa*, *IVb*).

The infrared spectra of *IVa*, *IVb* showed absorption band at 1620 cm<sup>-1</sup> characteristic of C=N group. Additionally, the mass spectrum of *IVa* showed the molecular ion M<sup>+</sup> at *m/z* = 311.

Also, the reaction of *IIa* and *IIb* with active nitriles such as malononitrile and ethyl cyanoacetate was studied. The reaction of *IIa*, *IIb* with malononitrile and ammonium acetate in ethanol afforded 3-cyano-2-imino-4-methoxy/4,8-dimethoxy-10-pentamethylene-10*H*-furo[3,2-*g*]pyrano[3,4-*c*][1]benzopyran (*Va*, *Vb*).

Structural assignments *Va*, *Vb* were based on elemental analysis, IR, <sup>1</sup>H NMR, and mass spectral data. The infrared spectra of *Va*, *Vb* revealed bands at 1616–1620 cm<sup>-1</sup>, 2200 cm<sup>-1</sup>, 3250 cm<sup>-1</sup> characteristic of C=N, C≡N, and NH groups, respectively.

Furthermore, the reaction of *IIa* with ethyl cyano-



Scheme 1

acetate in the presence of piperidine yielded 3-cyano-4-methoxy-10-pentamethylene-2-oxo-2*H*,10*H*-furo[3,2-*g*]pyrano[3,4-*c*][1]benzopyran (**VI**). This compound was also obtained by the reaction of **IIa** with malononitrile and ammonium acetate in acetic acid.

The assigned structure of **VI** was established on the basis of analytical and spectral data. The infrared spectrum of **VI** showed bands at 1720  $\text{cm}^{-1}$ , 2200  $\text{cm}^{-1}$  attributable to stretching vibration of  $\alpha,\beta$ -unsaturated  $\delta$ -lactone and  $\text{C}\equiv\text{N}$  groups, respectively. In addition, the mass spectrum revealed a molecular ion  $\text{M}^+$  at  $m/z = 363$ .

When *visnaginone* and *khellinone* were subjected to the Vilsmeier–Haack reaction, 4-methoxy/4,9-dimethoxy-5-oxo-5*H*-furo[3,2-*g*][1]benzopyran-6-carbaldehyde (**VIIa**, **VIIb**) was obtained [13] containing three potential sites of nucleophilic attack: C-7, C-5, and the 6-formyl group. Condensation of suitable reactant sites led to formation of a new ring system. So,

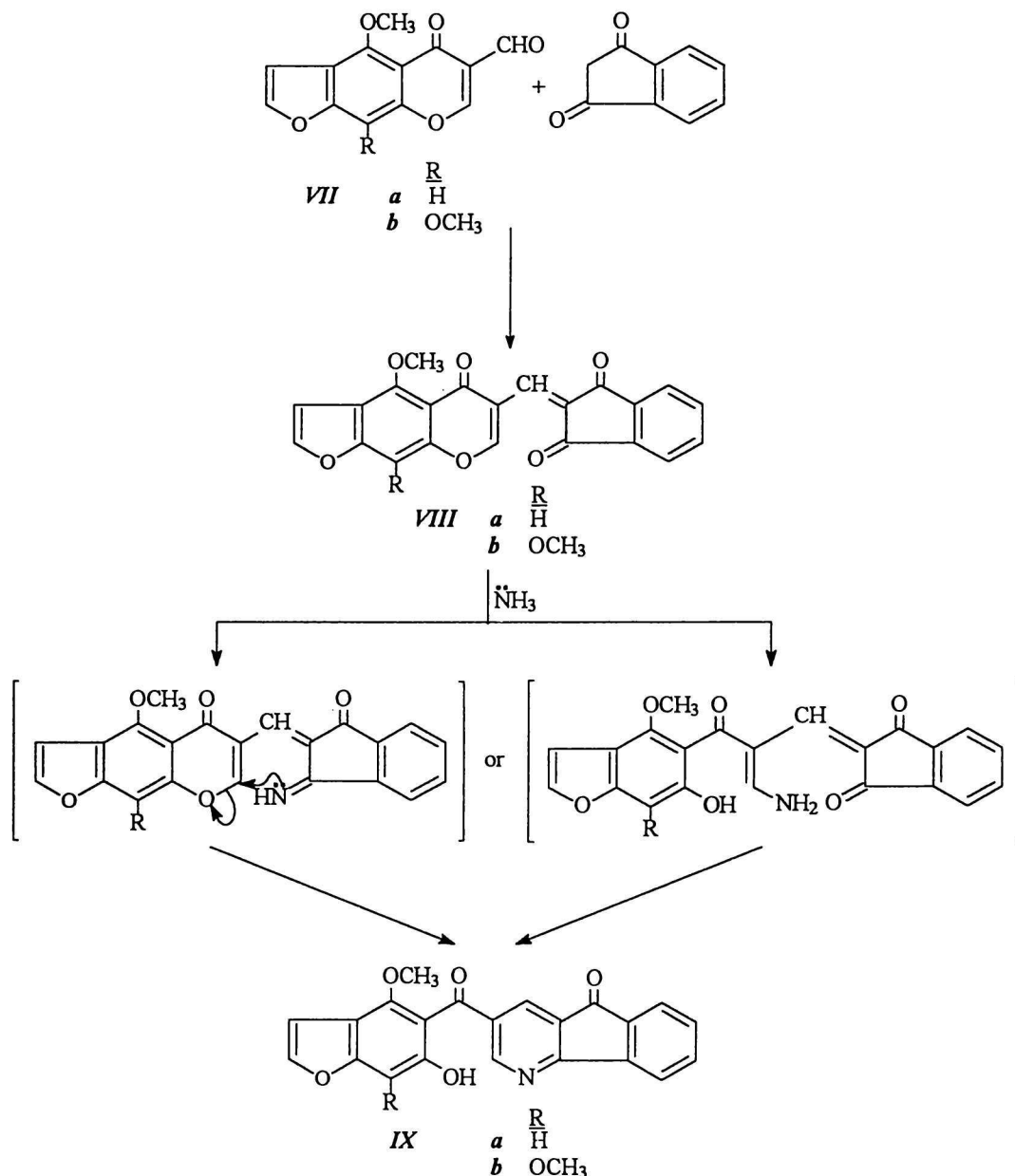
a variety of heterocyclic systems can be obtained.

Condensation reaction of **VIIa**, **VIIb** with indan-1,3-dione in pyridine with stirring at room temperature or in refluxing ethanol for 3 h gave 2-(4-methoxy/4,9-dimethoxy-5-oxo-5*H*-furo[3,2-*g*][1]benzopyran-6-ylmethylene)indan-1,3-dione (**VIIIa**, **VIIIb**).

Assignment of structures **VIIIa**, **VIIIb** was supported by elemental analysis, IR,  $^1\text{H}$  NMR, and mass spectral data. The infrared spectra showed absorption bands at 1618–1620  $\text{cm}^{-1}$ , 1648–1651  $\text{cm}^{-1}$ , 1685–1689  $\text{cm}^{-1}$  characteristic of  $\text{C}=\text{C}$ ,  $\text{C}=\text{O}$  (chromone), and  $\text{C}=\text{O}$  (indandione), respectively.

Treatment of compounds **VIIIa**, **VIIIb** with ammonia gave 3-(6-hydroxy-4-methoxy/4,7-dimethoxy-benzofuran-5-ylmethylene)-5-oxoindano[3,2-*b*]pyridine (**IXa**, **IXb**). This is in agreement with the previous findings [14].

The possible mechanism of the formation of **IXa**, **IXb** can be illustrated in Scheme 2.



Scheme 2

Assignment of structures *IXa*, *IXb* was confirmed by elemental analysis, IR and  $^1\text{H}$  NMR spectra. The infrared spectra of *IXa*, *IXb* revealed absorption bands at  $1620\text{ cm}^{-1}$ ,  $1630\text{ cm}^{-1}$ ,  $1722\text{--}1725\text{ cm}^{-1}$ , and  $3400\text{ cm}^{-1}$  attributable to  $\text{C}=\text{N}$ ,  $2\text{C}=\text{O}$ , and OH groups, respectively.

Condensation of *VIIa*, *VIIb* with dimedone (mole ratio 1 : 2) in pyridine gave 4-methoxy/4,9-dimethoxy-6-(3,3,6,6-tetramethyl-1,8-dioxo-1,2,3,4,5,6,7,8-octahydroxanthene-9-yl)-5-oxo-5H-furo[3,2-g][1]benzopyran (*Xa*, *Xb*) (Scheme 3). This is in agreement with the previous findings [14].

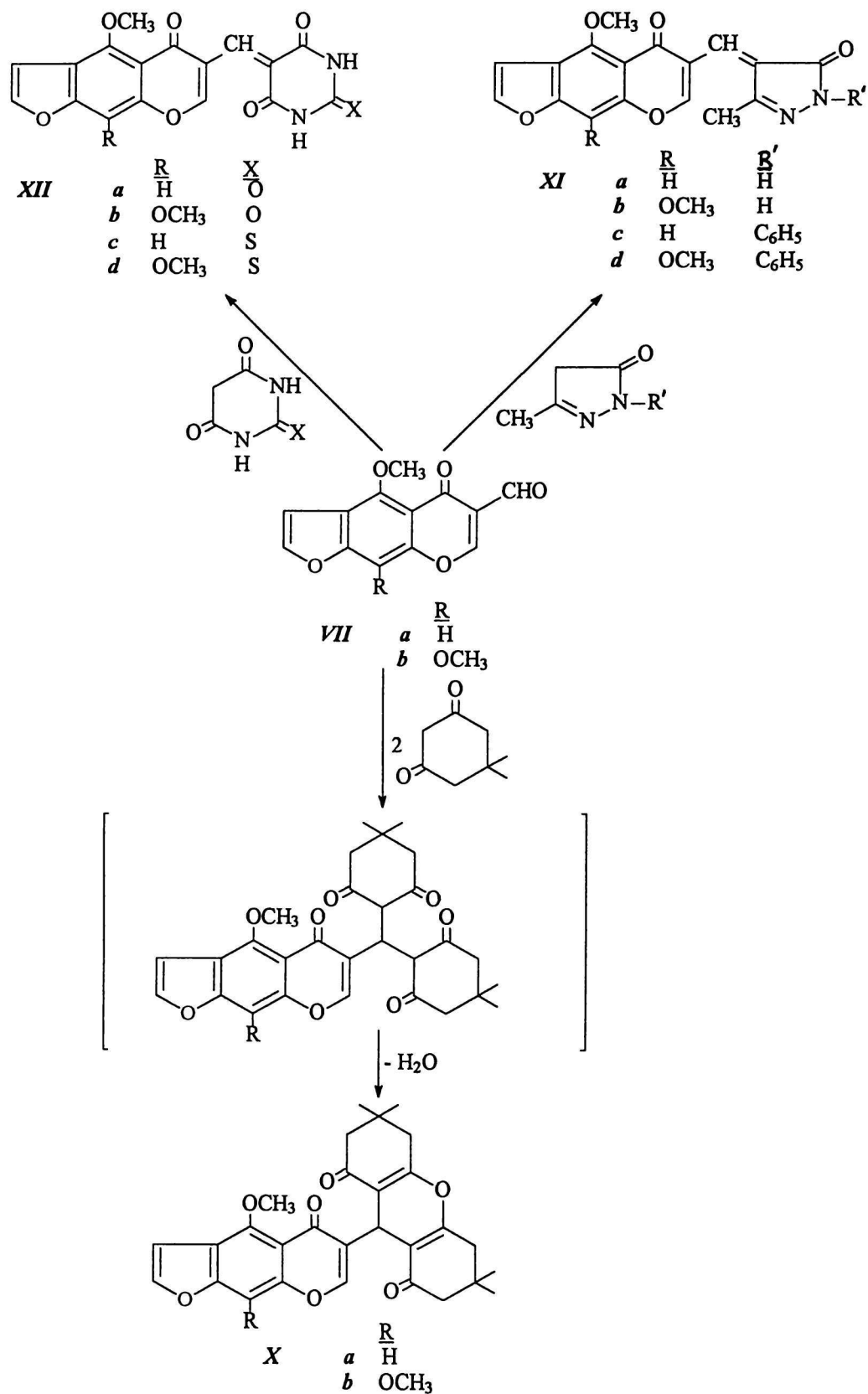
On the basis of elemental analysis, IR and  $^1\text{H}$  NMR spectra, structures *Xa*, *Xb* were assigned. The infrared spectra showed broad band at  $1660\text{ cm}^{-1}$  for  $\text{C}=\text{O}$

and bands at  $2875$ ,  $2956\text{ cm}^{-1}$  for CH groups.

The  $^1\text{H}$  NMR ( $\text{CDCl}_3$ ) spectrum of *Xb* showed signals at  $\delta$ : 0.90 (s, 6H, 2 $\text{CH}_3$ ), 1.00 (s, 6H, 2 $\text{CH}_3$ ), 2.13 (s, 4H, 2 $\text{CH}_2$ ), 2.4 (s, 4H, 2 $\text{CH}_2$ ), 3.8 (s, 3H,  $\text{OCH}_3$ ), 4.10 (s, 3H,  $\text{OCH}_3$ ), 4.50 (s, 1H, H-9'), 6.8 (d, 1H,  $J = 2\text{ Hz}$ , furan H-3), 7.60 (d, 1H,  $J = 2\text{ Hz}$ , furan H-2), and 8.25 (s, 1H, pyran H-7).

However, the reaction of *VIIa*, *VIIb* with 3-methyl-5-pyrazolone or 3-methyl-1-phenyl-5-pyrazolone in ethanol gave 4-(4-methoxy/4,9-dimethoxy-5-oxo-5H-furo[3,2-g][1]benzopyran-6-ylmethylene)-3-methylpyrazol-5-ones (*XIa*–*XId*). Structures *XIa*–*XId* were supported by elemental analysis and spectral data.

Moreover, the reaction of *VIIa*, *VIIb* with barbi-



Scheme 3

turic resp. thiobarbituric acid in ethanol yielded 5-(4-methoxy/4,9-dimethoxy-5-oxo-5*H*-furo[3,2-*g*][1]benzopyran-6-ylmethylene)barbituric resp. -thiobarbituric acids (*XIIa*—*XIId*).

Structural assignments *XIIa*—*XIId* were based upon the correct analytical and spectral data. The infrared spectra were compatible with the assigned structures.

Condensation products of *VIIa*, *VIIb* with dione, pyrazolone, barbituric resp. thiobarbituric acid failed to cyclize to pyridine derivatives in the presence of ammonia and resulted in recovery of starting material. In contrast to the ketone carbonyls described above, it appears that amide carbonyls of *XI*, *XII* as well as the vinylogous ester carbonyls of *X* are not sufficiently electrophilic to react with ammonia.

## EXPERIMENTAL

All melting points were uncorrected. Elemental analysis was carried out in Microanalytical Unit, Faculty of Science, Mansoura and Cairo University. Infrared spectra were recorded on Mattson 5000 FTIR spectrometer using KBr wafer technique. <sup>1</sup>H NMR spectra were determined on Varian-Gemini 200 MHz and Jeol Ex-270 MHz NMR Spectrometer using TMS as an internal standard with chemical shift  $\delta = 0$ . Mass spectra were determined on GC-MS QP-100 EX spectrometer Shimadzu (Japan). The purity of the synthesized compounds was tested by thin-layer chromatography (TLC): Merck Plates, Silica gel 60F<sub>254</sub>, layer thickness 0.2 mm. The characterization and spectral data of the new products are reported in Tables 1 and 2.

### 6-Hydroxymethylene-4-methoxy/4,9-dimethoxy-7-pentamethylene-7*H*-furo[3,2-*g*]-[1]benzopyran-5-one (*IIa*, *IIb*)

A solution of compound *Ia* or *Ib* (2.00 g) in ethyl formate (25 cm<sup>3</sup>) was slowly added to powdered sodium metal (2.00 g), when the initial vigorous reaction subsided; the reaction mixture was refluxed for 4 h on water bath, and then left to cool. Ethanol (5 cm<sup>3</sup>) was added to destroy any excess sodium metal. The reaction mixture was finally diluted with cold water and acidified with acetic acid to give oily substances that crystallized on standing at 0°C from ether.

### 3-Methoxy/3,7-dimethoxy-9-pentamethylene-9*H*-furo[3,2-*g*]pyrazolo[4,3-*c*][1]benzopyrans (*IIIa*—*IIId*)

A mixture of *IIa* or *IIb* (0.01 mol) and hydrazine hydrate or phenylhydrazine (0.01 mol) in ethanol (30 cm<sup>3</sup>) was refluxed for 5 h and then the solvent was concentrated to about 15 cm<sup>3</sup>, diluted with water and

left to cool. The solid that formed was filtered off, dried and crystallized from ethanol.

### 3-Methoxy/3,7-dimethoxy-9-pentamethylene-9*H*-furo[3,2-*g*]isoxazolo[4,3-*c*][1]benzopyran (*IVa*, *IVb*)

A solution of hydroxylammonium chloride (0.002 mol) and sodium acetate (0.002 mol) in a least amount of water was added to *IIa* or *IIb* (0.002 mol) in ethanol (30 cm<sup>3</sup>). The reaction mixture was refluxed for 5 h. The precipitated solid that was separated on cooling, was filtered off, dried and crystallized from benzene—petroleum ether.

### 3-Cyano-2-imino-4-methoxy/4,8-dimethoxy-10-pentamethylene-10*H*-furo[3,2-*g*]pyrano[3,4-*c*][1]benzopyran (*Va*, *Vb*)

A mixture of *IIa* or *IIb* (0.002 mol), malononitrile (0.002 mol), and ammonium acetate (0.002 mol) in ethanol (30 cm<sup>3</sup>) was refluxed for 3 h and then concentrated and diluted with water. The solid that formed was filtered off, dried and crystallized from ether—petroleum ether.

### 3-Cyano-4-methoxy-10-pentamethylene-2-oxo-2*H*,10*H*-furo[3,2-*g*]pyrano[3,4-*c*][1]benzopyran (*VI*)

A mixture of *IIa* (0.002 mol), ethyl cyanoacetate (0.002 mol), and 2—3 drops of piperidine in ethanol (30 cm<sup>3</sup>) was refluxed for 3 h and then concentrated and diluted with water. The solid that formed was filtered off, dried and crystallized from ether—petroleum ether.

### 2-(4-Methoxy/4,9-dimethoxy-5-oxo-5*H*-furo[3,2-*g*][1]benzopyran-6-ylmethylene)indan-1,3-dione (*VIIa*, *VIIb*)

A mixture of *VIIa* or *VIIb* (0.002 mol) and indan-1,3-dione (0.002 mol) in pyridine (10 cm<sup>3</sup>) was stirred at room temperature for 3 h. The reaction mixture was poured onto crushed ice, then acidified with 2 M-HCl. The precipitate that formed was filtered off, washed with ethanol, dried and crystallized from DMF.

### 3-(6-Hydroxy-4-methoxy/4,7-dimethoxy-benzofuran-5-ylmethylene)-5-oxoindano[3,2-*b*]pyridine (*IXa*, *IXb*)

A suspension of *VIIIa* or *VIIIb* (0.002 mol) in 5.5 cm<sup>3</sup> of concentrated aqueous ammonia and 10 cm<sup>3</sup> of water was refluxed for 1 h. The reaction was cooled to room temperature. The product was collected by filtration, washed with ethanol, dried and crystallized from a mixture of acetone and ethanol (1 : 1).

Table 1. Characterization Data of the Newly Prepared Compounds

Compound	Formula	$M_r$	$w_i$ (calc.)/% $w_i$ (found)/%			Yield %	M.p. °C
			C	H	N		
<i>Ia</i>	C <sub>18</sub> H <sub>18</sub> O <sub>5</sub>	314.34	68.78 68.59	5.77 5.69	— —	76	35—36
<i>Ib</i>	C <sub>19</sub> H <sub>20</sub> O <sub>6</sub>	344.36	66.27 66.08	5.85 6.00	— —	75	30—31
<i>IIIa</i>	C <sub>18</sub> H <sub>18</sub> N <sub>2</sub> O <sub>3</sub>	310.35	69.66 69.80	5.85 5.67	9.03 9.20	92	135—136
<i>IIIb</i>	C <sub>19</sub> H <sub>20</sub> N <sub>2</sub> O <sub>4</sub>	340.38	67.05 66.89	5.92 6.00	8.23 8.38	90	108—109
<i>IIIc</i>	C <sub>24</sub> H <sub>22</sub> N <sub>2</sub> O <sub>3</sub>	386.45	74.59 74.72	5.74 5.56	7.25 7.08	93	116—117
<i>IIIId</i>	C <sub>25</sub> H <sub>24</sub> N <sub>2</sub> O <sub>4</sub>	416.48	72.10 71.90	5.81 6.00	6.73 6.56	91	128—130
<i>IVa</i>	C <sub>18</sub> H <sub>17</sub> NO <sub>4</sub>	311.34	69.44 69.25	5.50 5.69	4.50 4.37	90	94—95
<i>IVb</i>	C <sub>19</sub> H <sub>19</sub> NO <sub>5</sub>	341.36	66.85 67.00	5.61 5.40	4.10 4.24	88	55—56
<i>Va</i>	C <sub>21</sub> H <sub>18</sub> N <sub>2</sub> O <sub>4</sub>	362.38	69.60 69.78	5.01 5.15	7.73 7.57	70	139—140
<i>Vb</i>	C <sub>22</sub> H <sub>20</sub> N <sub>2</sub> O <sub>5</sub>	392.41	67.34 67.48	5.14 5.00	7.14 7.29	72	120—121
<i>VI</i>	C <sub>21</sub> H <sub>17</sub> NO <sub>5</sub>	363.37	69.41 69.27	4.72 4.68	3.85 3.8	60	111—112
<i>VIIIa</i>	C <sub>22</sub> H <sub>12</sub> O <sub>6</sub>	372.33	70.97 70.82	3.25 3.17	— —	90	289—290
<i>VIIIb</i>	C <sub>23</sub> H <sub>14</sub> O <sub>7</sub>	402.36	68.66 68.82	3.51 3.38	— —	92	above 300
<i>IXa</i>	C <sub>22</sub> H <sub>13</sub> NO <sub>5</sub>	371.35	71.16 71.02	3.53 3.40	3.73 3.85	80	200—201
<i>IXb</i>	C <sub>23</sub> H <sub>15</sub> NO <sub>6</sub>	401.38	68.83 68.95	3.77 3.89	3.49 3.55	82	216—218
<i>Xa</i>	C <sub>29</sub> H <sub>28</sub> O <sub>7</sub>	488.54	71.30 71.14	5.78 5.65	— —	72	180—181
<i>Xb</i>	C <sub>30</sub> H <sub>30</sub> O <sub>8</sub>	518.56	69.49 69.60	5.83 5.96	— —	70	195—197
<i>XIa</i>	C <sub>17</sub> H <sub>12</sub> N <sub>2</sub> O <sub>5</sub>	324.29	62.96 63.00	3.73 3.57	8.64 8.47	85	227—228
<i>XIb</i>	C <sub>18</sub> H <sub>14</sub> N <sub>2</sub> O <sub>6</sub>	354.32	61.02 61.17	3.98 4.00	7.91 7.76	80	215—216
<i>XIc</i>	C <sub>23</sub> H <sub>16</sub> N <sub>2</sub> O <sub>5</sub>	400.39	69.00 69.08	4.03 3.98	7.00 6.88	83	199—200
<i>XId</i>	C <sub>24</sub> H <sub>18</sub> N <sub>2</sub> O <sub>6</sub>	430.42	66.97 66.88	4.22 4.03	6.51 6.68	82	229—230
<i>XIIa</i>	C <sub>17</sub> H <sub>10</sub> N <sub>2</sub> O <sub>7</sub>	354.28	57.64 57.45	2.85 2.73	7.91 8.05	92	275—276
<i>XIIb</i>	C <sub>18</sub> H <sub>12</sub> N <sub>2</sub> O <sub>8</sub>	384.30	56.26 56.40	3.15 3.32	7.29 7.18	95	289—290
<i>XIIc</i>	C <sub>17</sub> H <sub>10</sub> N <sub>2</sub> O <sub>6</sub> S	370.34	55.14 55.08	2.72 2.89	7.56 7.44	90	265—267
<i>XIIId</i>	C <sub>18</sub> H <sub>12</sub> N <sub>2</sub> O <sub>7</sub> S	400.36	54.00 54.18	3.02 3.15	7.00 6.87	93	above 300

**4-Methoxy/4,9-dimethoxy-6-(3,3,6,6-tetramethyl-1,8-dioxo-1,2,3,4,5,6,7,8-octahydroxanthren-9-yl)-5-oxo-5H-furo[3,2-g]-[1]benzopyran (*Xa*, *Xb*)**

To *VIIa* or *VIIb* (0.002 mol) and dimedone (0.004 mol) 10 cm<sup>3</sup> of pyridine was added under stirring. After 5 min, the reaction mixture became a homogeneous red solution. After 15 min the solution was rotary evaporated, acidified with 2 M-HCl and extracted

with 3 × 25 cm<sup>3</sup> of methylene chloride. The combined organic portions were dried over sodium sulfate and concentrated. The precipitate obtained after addition of ether was recrystallized from ethanol containing few drops of concentrated hydrochloric acid.

**4-(4-Methoxy/4,9-dimethoxy-5-oxo-5H-furo[3,2-g][1]benzopyran-6-ylmethylene)-3-methylpyrazol-5-ones (*XIa*—*XId*)**

Table 2. Spectral Data of the Newly Prepared Compounds

Compound	Spectral data
<i>IIa</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1655 (C=O), 3354 (OH) M.S.: $m/z = 314$ ( $M^+$ )
<i>IIb</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1656 (C=O), 3357 (OH) $^1\text{H NMR}$ ( $\text{CDCl}_3$ ), $\delta$ : 1.00–2.3 (m, 10H, 5CH <sub>2</sub> ), 4.00 (s, 3H, OCH <sub>3</sub> ), 4.15 (s, 3H, OCH <sub>3</sub> ), 5.9 (s, 1H, >C=CH), 6.9 (d, 1H, $J = 2$ Hz, furan H-3), 7.6 (d, 1H, $J = 2$ Hz, furan H-2), 7.7 (s, 1H, OH)
<i>IIIa</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1620 (C=N), 3246 (NH) $^1\text{H NMR}$ ( $\text{CDCl}_3$ ), $\delta$ : 1.3–2.2 (m, 10H, 5CH <sub>2</sub> ), 3.9 (s, 3H, OCH <sub>3</sub> ), 6.8 (s, 1H, H-6), 6.9 (d, 1H, $J = 2$ Hz, furan H-3), 7.6 (d, 1H, $J = 2$ Hz, furan H-2), 7.7 (bs, 1H, NH), 7.8 (s, 1H, pyrazole H-5)
<i>IIIb</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1618 (C=N), 3250 (NH)
<i>IIIc</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1619 (C=N) $^1\text{H NMR}$ ( $\text{CDCl}_3$ ), $\delta$ : 1.5–2.3 (m, 10H, 5CH <sub>2</sub> ), 3.7 (s, 3H, OCH <sub>3</sub> ), 6.7 (s, 1H, H-6), 6.9 (d, 1H, $J = 2$ Hz, furan H-3), 7.00–7.30 (m, 5H, H <sub>arom</sub> ), 7.5 (d, 1H, $J = 2$ Hz, furan H-2), 7.9 (s, 1H, pyrazole H-5) M.S.: $m/z = 386$ ( $M^+$ )
<i>IIId</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1620 (C=N) $^1\text{H NMR}$ ( $\text{CDCl}_3$ ), $\delta$ : 1.5–2.3 (m, 10H, 5CH <sub>2</sub> ), 3.8 (s, 3H, OCH <sub>3</sub> ), 4.00 (s, 3H, OCH <sub>3</sub> ), 6.9 (d, 1H, $J = 2$ Hz, furan H-3), 7.00–7.30 (m, 5H, H <sub>arom</sub> ), 7.5 (d, 1H, $J = 2$ Hz, furan H-2), 7.9 (s, 1H, pyrazole H-5) M.S.: $m/z = 416$ ( $M^+$ )
<i>IVa</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1619 (C=N) M.S.: $m/z = 311$ ( $M^+$ )
<i>IVb</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1620 (C=N) $^1\text{H NMR}$ ( $\text{CDCl}_3$ ), $\delta$ : 1.2–2.3 (m, 10H, 5CH <sub>2</sub> ), 3.99 (s, 3H, OCH <sub>3</sub> ), 4.10 (s, 3H, OCH <sub>3</sub> ), 6.8 (d, 1H, $J = 2$ Hz, furan H-3), 7.6 (d, 1H, $J = 2$ Hz, furan H-2), 8.00 (s, 1H, isoxazole H-5)
<i>Va</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1620 (C=N), 2205 (C≡N), 3250 (NH) M.S.: $m/z = 362$ ( $M^+$ )
<i>Vb</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1616 (C=N), 2200 (C≡N), 3240 (NH) $^1\text{H NMR}$ ( $\text{CDCl}_3$ ), $\delta$ : 1.2–2.2 (m, 10H, 5CH <sub>2</sub> ), 3.9 (s, 3H, OCH <sub>3</sub> ), 4.00 (s, 3H, OCH <sub>3</sub> ), 6.8 (d, 1H, $J = 2$ Hz, furan H-3), 7.6 (d, 1H, $J = 2$ Hz, furan H-2), 8.20 (s, 1H, H-11)
<i>VI</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1720 ( $\alpha,\beta$ -unsaturated $\delta$ -lactone), 2200 (C≡N) M.S.: $m/z = 363$ ( $M^+$ )
<i>VIIIa</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1618 (C=C), 1648 (C=O chromone), 1685 (C=O indandione) $^1\text{H NMR}$ (DMSO), $\delta$ : 20 (s, 3H, OCH <sub>3</sub> ), 7.20 (d, 1H, $J = 2$ Hz, furan H-3), 7.3–7.80 (m, 5H, 4H <sub>arom</sub> , H-9), 8.00 (d, 1H, $J = 2$ Hz, furan H-2), 8.4 (s, 1H, pyran H-7), 10.12 (s, 1H, —CH=C<)
<i>VIIIb</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1620 (C=C), 1651 (C=O chromone), 1689 (C=O indandione) M.S.: $m/z = 402$ ( $M^+$ )
<i>IXa</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1620 (C=N), 1630, 1725 (2C=O), 3400 (OH)
<i>IXb</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1619 (C=N), 3400 (OH), 1630, 1722 (2C=O), 3400 (OH) $^1\text{H NMR}$ ( $\text{CDCl}_3$ ), $\delta$ : 3.76 (s, 3H, OCH <sub>3</sub> ), 4.10 (s, 3H, OCH <sub>3</sub> ), 6.8 (d, 1H, $J = 2$ Hz, furan H-3), 7.50–7.90 (m, 5H, 4H <sub>arom</sub> , furan H-2), 8.10 (d, 1H, pyridine), 8.9 (d, 1H, pyridine H), 9.4 (s, 1H, OH)
<i>Xa</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1620 (C=C), 2874, 2956 (CH), 1661 (C=O), 2956, 2874 (CH)
<i>Xb</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1919 (C=C), 1660 (C=O), 2957, 2875 (CH) $^1\text{H NMR}$ ( $\text{CDCl}_3$ ), $\delta$ : 0.90 (s, 6H, 2CH <sub>3</sub> ), 1.00 (s, 6H, 2CH <sub>3</sub> ), 2.13 (s, 4H, 2CH <sub>2</sub> ), 2.4 (s, 4H, 2CH <sub>2</sub> ), 3.8 (s, 3H, OCH <sub>3</sub> ), 4.1 (s, 3H, OCH <sub>3</sub> ), 4.50 (s, 1H, H-9'), 6.8 (d, 1H, $J = 2$ Hz, furan H-3), 7.60 (d, 1H, $J = 2$ Hz, furan H-2), 8.25 (s, 1H, H-7)
<i>XIa</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1600 (C=N), 1620, 1645 (C=O), 3259 (NH)
<i>XIb</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1602 (C=N), 1620, 1646 (C=O), 3260 (NH) $^1\text{H NMR}$ (DMSO), $\delta$ : 2.4 (s, 1H, CH <sub>3</sub> ), 3.85 (s, 3H, OCH <sub>3</sub> ), 3.95 (s, 3H, OCH <sub>3</sub> ), 7.2 (d, 1H, $J = 2$ Hz, furan H-3), 7.3 (s, 1H, —CH=C<), 8.00 (d, 1H, $J = 2$ Hz, furan H-2), 8.2 (s, 1H, pyran H-7), 8.70 (s, 1H, NH)
<i>XIc</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1600 (C=N), 1650, 1676 (C=O) $^1\text{H NMR}$ ( $\text{CDCl}_3$ ): $\delta$ : 2.4 (s, 3H, CH <sub>3</sub> ), 4.2 (s, 3H, OCH <sub>3</sub> ), 7.00 (d, 1H, $J = 2$ Hz, furan H-3), 7.10–7.95 (m, 8H, (5H <sub>arom</sub> , H-9, —CH=C<, furan H-2)), 8.10 (s, 1H, pyran H-7)
<i>XId</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1605 (C=N), 1651, 1677 (C=O) $^1\text{H NMR}$ ( $\text{CDCl}_3$ ), $\delta$ : 2.4 (s, 3H, CH <sub>3</sub> ), 4.1 (s, 3H, OCH <sub>3</sub> ), 4.2 (s, 3H, OCH <sub>3</sub> ), 7.00 (d, 1H, $J = 2$ Hz, furan H-3), 7.2–8.00 (m, 7H, 5-H <sub>arom</sub> , —CH=C<, furan H-2), 8.10 (s, 1H, pyran H-7)
<i>XIIa</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1678, 1703, 1750 (C=O), 3161, 3197 (NH) M.S.: $m/z = 354$ ( $M^+$ ) $^1\text{H NMR}$ (DMSO), $\delta$ : 4.10 (s, 3H, OCH <sub>3</sub> ), 7.20 (d, 1H, $J = 2$ Hz, furan H-3), 7.30 (s, 1H, H-9), 8.00 (d, 1H, $J = 2$ Hz, furan H-2), 8.4 (s, 1H, pyran H-7), 9.6 (s, 1H, —CH=C<), 11.3 (s, 1H, NH), 11.4 (s, 1H, NH)
<i>XIIb</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1674, 1703, 1752 (C=O), 3160, 3200 (NH) $^1\text{H NMR}$ (DMSO), $\delta$ : 3.95 (s, 3H, OCH <sub>3</sub> ), 4.10 (s, 3H, OCH <sub>3</sub> ), 7.20 (d, 1H, $J = 2$ Hz, furan H-3), 8.00 (d, 1H, $J = 2$ Hz, furan H-2), 8.5 (s, 1H, pyran H-7), 9.7 (s, 1H, —CH=C<), 11.3 (s, 1H, NH), 11.4 (s, 1H, NH)
<i>XIIc</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1672, 1700 (C=O), 3120, 3213 (NH)
<i>XIId</i>	IR: $\bar{\nu}/\text{cm}^{-1}(\nu)$ : 1670, 1700 (C=O), 3121, 3215 (NH) $^1\text{H NMR}$ (DMSO), $\delta$ : 4.00 (s, 3H, OCH <sub>3</sub> ), 4.1 (s, 3H, OCH <sub>3</sub> ), 7.2 (d, 1H, $J = 2$ Hz, furan H-3), 8.00 (d, 1H, $J = 2$ Hz, furan H-2), 8.42 (s, 1H, pyran H-7), 9.7 (s, 1H, —CH=C<), 12.30 (s, 1H, NH), 12.40 (s, 1H, NH)



A mixture of *VIIa* or *VIIb* (0.002 mol) and 3-methylpyrazol-5-one or 3-methyl-1-phenylpyrazol-5-one (0.002 mol) was refluxed in ethanol (30 cm<sup>3</sup>) for 2 h. The solid that formed was filtered off, dried and recrystallized from ethanol.

**5-(4-Methoxy/4,9-dimethoxy-5-oxo-5H-furo[3,2-g][1]benzopyran-6-ylmethylene)-barbituric resp. -thiobarbituric acids (*XIIa*—*XIIId*)**

A mixture of *VIIa* or *VIIb* (0.002 mol) and barbituric or thiobarbituric acid (0.002 mol) was refluxed in ethanol (30 cm<sup>3</sup>) for 2 h. The solid that formed was filtered off, dried and recrystallized from DMF.

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