SYNTHESIS OF PYRANO[2,3-*f*]CHROMEN-2,8-DIONES AND PYRANO[3,2-*g*]CHROMEN-2,8-DIONES BASED ON *o*-HYDROXYFORMYL(ACYL)NEOFLAVONOIDS

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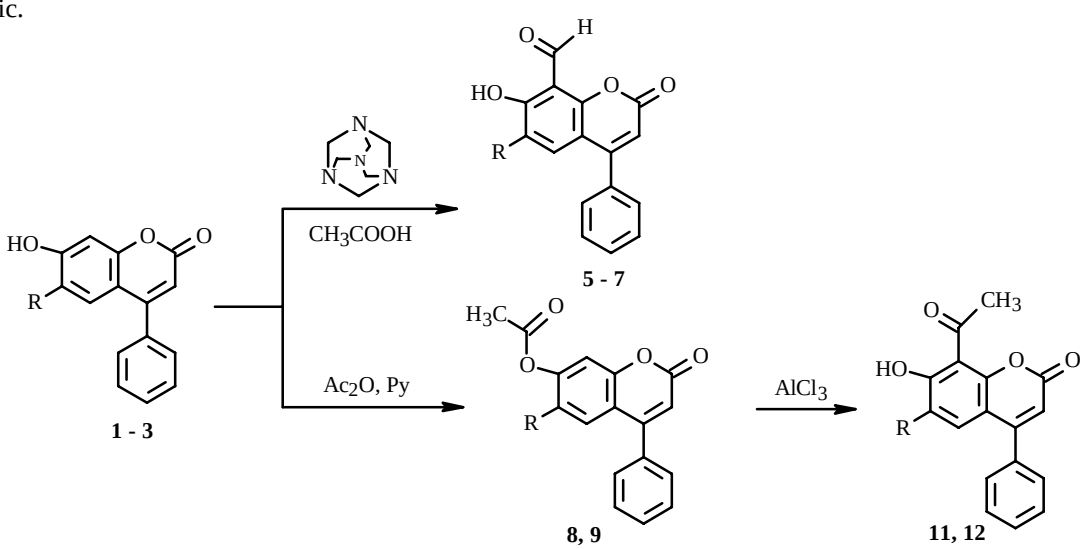
Novel pyrano[2,3-f]chromen-2,8-diones and pyrano[3,2-g]chromen-2,8-diones were prepared based on modified analogs of natural o*-hydroxyformyl(acyl)neoflavonoids.*

Key words: Neoflavonoids, formylcoumarins, acylcoumarins, pyrano[2,3-*f*]chromen-2,8-diones, pyrano[3,2-*g*]chromen-2,8-diones.

Neoflavonoids of the 4-phenylcoumarin group that is widely distributed in nature [1] exhibit insecticidal and antibacterial [2-5], antiatherosclerotic [6], anticonvulsive, antituberculosis, antimalarial [7], and cytotoxic activity [8, 9]; inhibit monophosphate adenosin-3′,5′-cyclase; act as anti-HIV agents [10]; inhibit proteinkinase activity; and are widely used as antioxidants [11], pesticides, and bactericides.

We prepared starting 7-hydroxy-4-phenylcoumarins **1-4** via condensation of the corresponding phenols and ethylbenzoylacetate in the presence of catalytic amounts of H_2SO_4. Neoflavonoids **1-3** were formylated in glacial acetic acid by urotropine using the Duff reaction to give exclusively 7-hydroxy-8-formyl-4-phenylcoumarins **5**, **6**, and **7**. The structures of the *o*-hydroxyformylcoumarins were proved by PMR spectroscopy. A weak-field singlet at 12.05-12.53 ppm for the 7-OH group due to formation of an intramolecular H-bond and a resonance for the formyl group at 10.56-10.57 ppm were characteristic.



1, 5: R = H; **2, 6, 8, 11:** R = Et; **3, 7, 9, 12:** R = Pr

o-Hydroxyacyl-4-phenylcoumarins **11-13** were prepared in two steps via acylation with acetic anhydride in pyridine of the corresponding neoflavones **2-4** followed by Fries rearrangement of the resulting acetoxycoumarins **8-10** using $AlCl_3$. The

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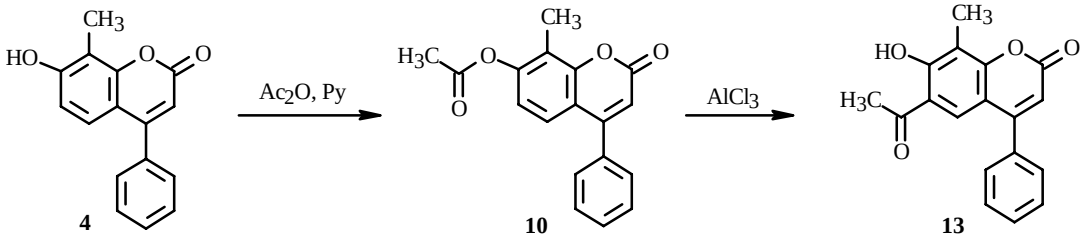
PMR spectra of **11-13** exhibited a weak field singlet at 12.96-13.75 ppm for the OH group, which formed an intramolecular H-bond with the *o*-acyl group.



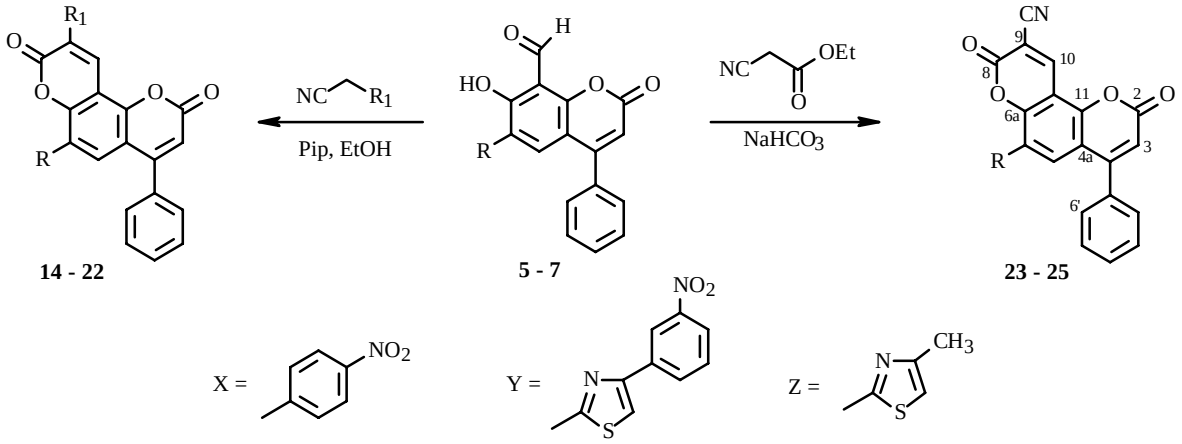
4 **10** **13**

The resulting formylated neoflavonoids were modified analogs of the recently observed scarce group of natural formylcoumarins that includes voludala, a minor component of *Dalbergia volubilic* [12]; yunngnin A and B (isolated from *Hercaleum yunngningense* roots [13]); sisafolin isolated from *D. latifolia* [14], and crenulatin, obtained from *Hesperathusa crenulata* [15].

Acylated coumarins are more widely distributed in nature. Examples of such compounds are racemosone, isolated from *Mesua racemosa* [16]; isodispar B, obtained from *Calophyllum dispar* and exhibiting cytotoxic activity [17]; acetylumbelliferone, from *Daphne gnidiodes* [18]; 7-hydroxy-6-acylcoumarin, isolated from *Apium petroselinum* [19]; and 8-acetyl-7-hydroxy-6-methoxychromen-2-one, obtained from *Fraxinus floribunda* [20].

Natural and synthetic analogs of *o*-hydroxyformyl(acyl)coumarins exhibit various pharmacological properties. Formylcoumarins are typically antifungal [21] and antituberculosis agents [22]. Acylcoumarins have anti-inflammatory [23], antimicrobial [24], antifungal [21], and antituberculosis [22] activities and act as inhibitors of arylhydrocarbonhydroxylase [25, 26].

Compounds **5-7** and **11-13** were next used as starting materials to prepare pyrano[2,3-*f*]chromen-2,8-diones and pyrano[3,2-*g*]chromen-2,8-diones. Several methods are known for constructing this system. Thus, using *o*-hydroxyformyl(acyl)coumarins in a Pechmann reaction [27] and reaction with acetylglycine [28], ethoxycarbonylmethylenetriphenylphosphorane [29], and maleic acid (Pechmann reaction) [30], the corresponding pyrano[2,3-*f*]chromen-2,8-diones were prepared. In our opinion, the most convenient method for preparing this system is condensation of substituted acetophenons with phenylacetylchloride [31, 32].



14 - 22 **5 - 7** **23 - 25**

X = Y = Z =

14 - 16, 23: R = H, **17 - 19, 24:** R = Et; **20 - 22, 25:** R = Pr; **14, 17, 20:** R_1 = X; **15, 18, 21:** R_1 = Y; **16, 19, 21:** R_1 = Z

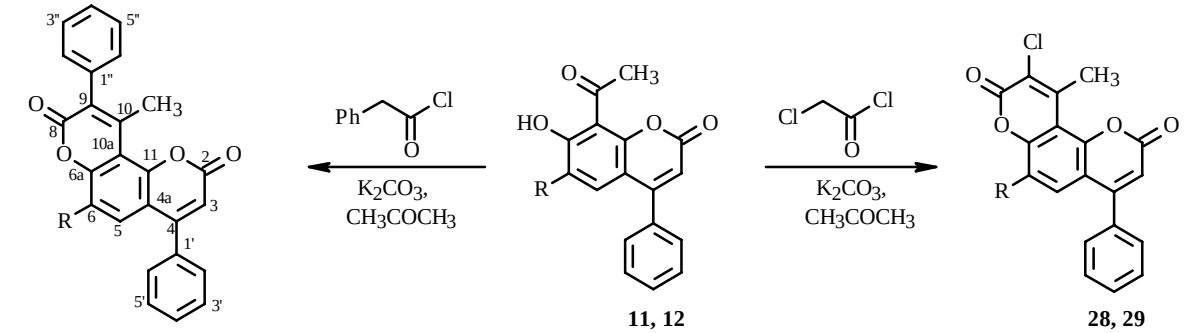
Reaction of formyl derivatives **5-7** with hetarylacetonitriles under mild conditions at room temperature in the presence of piperidine as the base followed by acid hydrolysis produced the corresponding 2*H*,8*H*-pyrano[2,3-*f*]chromen-4-phenyl-9-aryl(hetaryl)-2,8-diones **14-22**.

The hydrolysis time of the intermediate iminocoumarins depended on the 9-aryl substituent. Thus, the hydrolysis time for the 4-nitrophenyl substituent was about 1 h; for methyl- and phenylthiazolylcoumarins, 24-36 h. Hydrolysis of the imino group was monitored using TLC. PMR spectra of **14-22** contained a characteristic singlet for the 10-H proton at weak field at 8.56-9.19 ppm.

TABLE 1. ^{13}C NMR Spectra of **23 - 25**

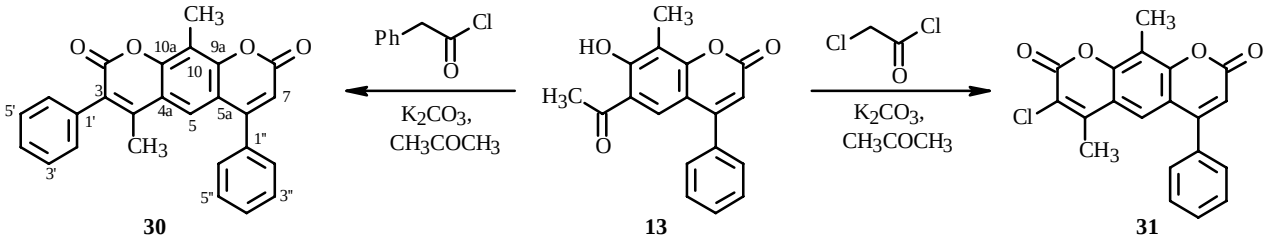
C atom	Compound		
	23	**24**	**25**
2	160.8	160.8	160.8
3	112.7	112.7	112.7
4	155.4	155.4	155.4
4a	116.9	116.8	117.0
5	126.4	125.3	125.7
6	118.2	129.6	128.2
6a	149.7	148.7	149.1
8	156.6	156.6	156.6
9	100.1	100.0	100.3
10	119.5	119.8	119.7
10a	123.9	123.8	124.0
11	145.8	143.0	143.1
1′	142.0	140.0	141.0
2′, 6′	126.7	126.4	126.5
3′, 5′	128.7	128.7	128.7
4′	128.0	128.0	128.0
CN	115.8	115.8	115.8
1″	-	27.2	33.0
2″	-	14.5	24.1
3″	-	-	13.7

Reaction of formyl derivatives **5-7** with ethylcyanoacetate in the presence of $NaHCO_3$ followed by acid hydrolysis produced the corresponding 2*H*,8*H*-pyrano[2,3-*f*]chromen-4-phenyl-9-carbonitriles **23-25**. PMR spectra of the products showed a singlet at 8.89-9.1 ppm for the 10-H proton. A resonance at 116 ppm in the ^{13}C NMR spectra corresponded to the 9-CN group (Table 1).



26, 27 **11, 12** **28, 29**

26, 28: R = Et; **27, 29:** R = Pr



30 **13** **31**

The reaction of aceylneoflavonoids **11-13** with phenylacetylchloride and chloroacetylchloride required more forcing conditions than for formylneoflavonoids **5-7**, i.e., boiling in acetone with K_2CO_3 for 9-10 h, and formed the corresponding pyrano[2,3-*f*]chromen-2,8-diones **26-29** with an angular structure and pyrano[3,2-*g*]chromen-2,8-diones **30-31** with a linear structure.

TABLE 2. ^{13}C NMR Spectra of **26** - **29**

C atom	Compound			
	26	**27**	**28**	**29**
2	160.8	160.3	160.7	160.9
3	112.2	112.4	112.7	112.3
4	155.4	155.3	155.6	155.2
4a	116.8	117.0	116.8	117.0
5	125.3	125.7	125.3	125.7
6	129.6	128.2	129.6	128.2
6a	148.7	149.1	148.7	149.1
8	161.9	161.9	158.6	158.6
9	122.0	122.0	116.3	116.3
10	144.0	144.0	148.9	148.9
10a	119.5	119.7	119.5	119.7
11	143.0	143.1	143.0	143.1
1′	140.0	140.2	140.3	140.0
2′, 6′	126.8	126.8	126.6	126.6
3′, 5′	128.7	128.7	128.7	128.7
4′	128.0	128.0	128.0	128.0
1″	132.5	132.5	-	-
2″, 6″	126.4	126.4	-	-
3″, 5″	128.7	128.7	-	-
4″	128.0	128.0	-	-
1‴	27.2	33.0	27.2	33.0
2‴	14.5	24.1	14.5	24.1
3‴	-	13.7	-	13.7
10-CH_3	14.5	14.5	12.0	12.0

TABLE 3. ^{13}C NMR Spectra of **30** - **31**

C atom	Compound	
	30	**31**
2	161.9	158.6
3	122.0	116.3
4	144.0	148.9
4a	117.6	117.8
5	120.4	120.6
5a	116.8	116.6
6	155.6	155.4
7	112.7	112.5
8	160.9	160.8
9a	150.1	150.0
10	126.2	126.3
10a	150.0	150.0
1′	132.5	140.0
2′,6′	126.6	126.7
3′,5′	128.7	128.7
4′	128.0	128.0
1″	140.0	-
2″,6″	126.4	-
3″,5″	128.7	-
4″	128.0	-
4-CH_3	14.5	12.0
10-CH_3	13.1	13.3

The structures of **26-31** were proved using PMR and ^{13}C NMR spectroscopy. Thus, PMR spectra lacked resonances for the 7-OH group. ^{13}C NMR spectra (Tables 2 and 3) of **26-31** contained characteristic resonances for carbonyls of the pyrano-2-one moieties at 158.6-162 ppm.

EXPERIMENTAL

The course of reactions and purity of products were monitored by TLC on Merck F254 plates with elution by $CHCl_3$:CH_3OH (9:1 and 95:5). Melting points were measured on a Kofler block. PMR spectra in DMSO-d_6 and trifluoroacetic acid (TFA) were recorded on a Mercury-400 spectrometer (400 MHz for ^1H and 100 MHz for ^{13}C) relative to TMS (internal standard). Elemental analyses of all compounds agreed with those calculated.

Hydroxycoumarins **1**, **2**, **3**, and **4** were prepared as before [33]. Melting points and PMR spectra agreed with those in the literature.

General Method for Formylation of 7-Hydroxyneoflavonoids. A solution of the appropriate 7-hydroxyneoflavone (5 mmol) and hexamethylenetetramine (7 g, 50 mmol) in acetic acid (20 mL) was heated on a water bath for 6-8 h, poured into HCl (24 mL, 17%), boiled for 10 min, and treated with water (40 mL). The resulting solid was filtered off after several hours and crystallized from ethanol.

7-Hydroxy-2-oxo-4-phenyl-2*H*-chromen-8-carbaldehyde (5). Yield 0.8 g (60.15%), $C_{16}H_{10}O_4$, mp 120°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 6.24 (1H, s, H-3), 6.85 (1H, d, J = 9.2, H-6), 7.47 (2H , m, H-2′, H-6′), 7.53 (3H, m, H-3′, H-4′, H-5′), 7.61 (1H, d, J = 9.2, H-5), 10.57 (1H, s, 8-CHO), 12.05 (1H, s, 7-OH).

6-Ethyl-7-hydroxy-2-oxo-4-phenyl-2*H*-chromen-8-carbaldehyde (6). Yield 0.67 g (50.75%), $C_{18}H_{14}O_4$, mp 138-140°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 1.12 (3H, m, CH_3CH_2-6), 2.53 (2H, t, J = 6.4, CH_3CH_2-6), 6.22 (1H, s, H-3), 7.2 (1H, s, H-5), 7.47 (2H, m, H-2′, H-6′), 7.54 (3H, m, H-3′, H-4′, H-5′), 10.57 (1H, s, 8-CHO), 12.53 (1H, s, 7-OH).

7-Hydroxy-2-oxo-4-phenyl-6-propyl-2*H*-chromen-8-carbaldehyde (7). Yield 0.61 g (43.8%), $C_{19}H_{16}O_4$, mp 136-137°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 0.91 (3H, m, $CH_3CH_2CH_2$-6), 1.52 (2H, m, $CH_3CH_2CH_2$-6), 2.47 (2H, t, J = 7.6, $CH_3CH_2CH_2$-6), 6.21 (1H, s, H-3), 7.07 (1H, s, H-5), 7.49 (2H, m, H-2′, H-6′), 7.58 (3H, m, H-3′, H-4′, H-5′), 10.56 (1H, s, 8-CHO), 12.53 (1H, s, 7-OH).

General Method for Acylation of 7-Hydroxyneoflavonoids. A suspension of the appropriate 7-hydroxyneoflavone (15 mmol) in acetic anhydride (30 mmol) was heated with a catalytic amount of pyridine (2-3 drops) until totally dissolved, left at room temperature until a precipitate formed, poured into icewater (200 mL), and filtered. The solid was crystalized from methanol.

6-Ethyl-7-acetoxy-4-phenylchromen-2-one (8). Yield 3.2 g (80.2%), $C_{19}H_{16}O_4$, mp 152-154°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 1.11 (3H, m, CH_3CH_2-6), 2.35 (3H, s, CH_3COO-7), 2.52 (2H, t, J = 6.4, CH_3CH_2-6), 6.28 (1H, s, H-3), 7.22 (1H, s, H-5), 7.32 (1H, s, H-8), 7.51 (2H, m, H-2′, H-6′), 7.56 (3H, m, H-3′, H-4′, H-5′).

7-Acetoxy-4-phenyl-6-propylchromen-2-one (9). Yield 4.6 g (95.13%), $C_{20}H_{18}O_4$, mp 128-129°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 0.91 (3H, m, $CH_3CH_2CH_2$-6), 1.51 (2H, m, $CH_3CH_2CH_2$-6), 2.35 (3H, s, CH_3COO-7), 2.45 (2H, t, J = 7.6, $CH_3CH_2CH_2$-6), 6.29 (1H, s, H-3), 7.23 (1H, s, H-5), 7.31 (1H, s, H-8), 7.51 (2H, m, H-2′, H-6′), 7.56 (3H, m, H-3′, H-4′, H-5′).

7-Acetoxy-8-methyl-4-phenylchromen-2-one (10). Yield 3.98 g (90.15%), $C_{18}H_{14}O_4$, mp 189-190°C (lit. [34] mp 140°C, [35] 188-188.5°C).

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 2.28 (3H, s, CH_3-8), 2.36 (3H, s, CH_3COO-7), 6.31 (1H, s, H-3), 7.01 (1H, d, J = 8.8, H-6), 7.33 (1H, d, J = 8.4, H-5), 7.49 (2H, m, H-2′, H-6′), 7.55 (3H, m, H-3′, H-4′, H-5′).

General Method for Preparing *o*-Hydroxyacylcoumarins. A mixture of the appropriate 7-acetoxyneoflavone (15 mmol) and $AlCl_3$ (75 mmol) was heated at 120°C with vigorous stirring for 1 h, cooled, and mixed with HCl (100 mL, 1 N). The resulting precipitate was filtered off and crystallized from propan-2-ol.

8-Acetyl-6-ethyl-7-hydroxy-4-phenylchromen-2-one (11). Yield 2.7 g (67.66%), $C_{19}H_{16}O_4$, mp 144-145°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 1.11 (3H, m, CH_3CH_2-6), 2.59 (2H, t, J = 7.2, CH_3CH_2-6), 2.93

(3H, s, CH_3CO-8), 6.18 (1H, s, H-3), 7.36 (1H, s, H-5), 7.44 (2H, m, H-2′, H-6′), 7.56 (3H, m, H-3′, H-4′, H-5′), 13.74 (1H, s, OH-7).

8-Acetyl-7-hydroxy-4-phenyl-6-propylchromen-2-one (12). Yield 3.9 g (80.74%), $C_{20}H_{18}O_4$, mp 187-188°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 0.91 (3H, m, $CH_3CH_2CH_2$-6), 1.52 (2H, m, $CH_3CH_2CH_2$-6), 2.45 (2H, t, J = 7.6, $CH_3CH_2CH_2$-6), 2.92 (3H, s, CH_3CO-8), 6.18 (1H, s, H-3), 7.33 (1H, s, H-5), 7.43 (2H, m, H-2′, H-6′), 7.55 (3H, m, H-3′, H-4′, H-5′), 13.75 (1H, s, OH-7).

6-Acetyl-7-hydroxy-8-methyl-4-phenylchromen-2-one (13). Yield 3.26 g (73.9%), $C_{18}H_{14}O_4$, mp 201-202°C (lit. [36] mp 203°C).

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm): 2.27 (3H, s, CH_3-8), 2.46 (3H, s, CH_3COO-7), 6.21 (1H, s, H-3), 7.50 (5H, m, H-2′, H-3′, H-4′, H-5′, H-6′), 7.82 (1H, s, H-5), 12.95 (1H, s, OH-7).

General Method for Preparing 14-22.

A solution of the appropriate 7-hydroxy-8-formylneoflavone (1 mmol) and the corresponding aryl(hetaryl)acetonitrile (1 mmol) in ethanol was treated with several drops of piperidine and left at room temperature for 24 h. The resulting precipitated iminocoumarin was mixed with aqueous H_2SO_4 (5%) and heated on a water bath for 1-36 h. The course of the reaction was monitored by TLC. When the reaction was finished, the precipitate was filtered off and crystallized from ethanol.

9-(4-Nitrophenyl)-4-phenylpyrano[2,3-*f*]chromen-2,8-dione (14). Yield 0.16 g (38.9%), $C_{24}H_{13}O_6$, mp 249-250°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 6.42 (1H, s, H-3), 7.34 (1H, d, J = 9.2, H-6), 7.56 (5H, m, H-2′, H-3′, H-4′, H-5′, H-6′), 7.70 (1H, d, J = 8.8, H-5), 8.09 (2H, d, J = 8.8, H-3″, H-5″), 8.31 (2H, d, J = 8.8, H-2″, H-6″), 8.56 (1H, s, H-10).

9-[4-(3-Nitrophenyl)thiazol-2-yl]-4-phenylpyrano[2,3-*f*]chromen-2,8-dione (15). Yield 0.25 g (50.6%), $C_{27}H_{14}N_2O_6S$, mp 332-333°C.

PMR spectrum (400 MHz, TFA, δ, ppm, J/Hz): 6.85 (1H, s, H-3), 7.57 (H-6, d, J = 8.4, H-6), 7.61 (5H, m, H-2′, H-3′, H-4′, H-5′, H-6′), 7.66 (1H, d, J = 8.4, H-5), 7.96 (1H, t, J = 8, H-5‴), 8.28 (1H, s, H-2‴), 8.30 (1H, d, J = 8, H-6‴), 8.48 (1H, s, H-3″), 8.62 (1H, d, J = 8, H-4‴), 8.85 (1H, s, H-10).

9-(4-Methylthiazol-2-yl)-4-phenylpyrano[2,3-*f*]chromen-2,8-dione (16). Yield 0.09 g (23.3%), $C_{22}H_{13}NO_4S$, mp 263-264°C.

PMR spectrum (400 MHz, TFA, δ, ppm, J/Hz): 2.87 (3H, s, CH_3-4″), 6.86 (1H, s, H-3), 7.62 (1H, d, J = 9.2, H-6), 7.69 (5H, m, H-2′, H-3′, H-4′, H-5′, H-6′), 7.83 (1H, s, H-3″), 8.28 (1H, d, J = 9.2, H-5), 9.19 (1H, s, H-10).

6-Ethyl-9-(4-nitrophenyl)-4-phenylpyrano[2,3-*f*]chromen-2,8-dione (17). Yield 0.12 g (23.7%), $C_{26}H_{17}NO_6$, mp 286-287°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 1.11 (3H, m, CH_3CH_2-6), 2.59 (2H, t, J = 7.2, CH_3CH_2-6), 6.41 (1H, s, H-3), 7.45 (1H, s, H-5), 7.57 (5H, m, H-2′, H-3′, H-4′, H-5′, H-6′), 8.10 (2H, d, J = 8.8, H-3″, H-5″), 8.32 (2H, d, J = 8.8, H-2″, H-6″), 8.57 (1H, s, H-10).

6-Ethyl-9-[4-(3-nitrophenyl)thiazol-2-yl]-4-phenylpyrano[2,3-*f*]chromen-2,8-dione (18). Yield 0.15 g (28.7%), $C_{29}H_{18}N_2O_6S$, mp 239-240°C.

PMR spectrum (400 MHz, TFA, δ, ppm, J/Hz): 1.09 (3H, m, CH_3CH_2-6), 2.57 (2H, t, J = 7.2, CH_3CH_2-6), 6.83 (1H, s, H-3), 7.62 (5H, m, H-2′, H-3′, H-4′, H-5′, H-6′), 7.66 (1H, s, H-5), 7.94 (1H, t, J = 8, H-5‴), 8.29 (1H, s, H-2‴), 8.31 (1H, d, J = 8, H-6‴), 8.46 (1H, s, H-3″), 8.62 (1H, d, J = 8, H-4‴), 8.86 (1H, s, H-10).

6-Ethyl-9-(4-methylthiazol-2-yl)-4-phenylpyrano[2,3-*f*]chromen-2,8-dione (19). Yield 0.11 g (26.5%), $C_{24}H_{17}NO_4S$, mp 289-290°C.

PMR spectrum (400 MHz, TFA, δ, ppm, J/Hz): 1.23 (3H, m, CH_3CH_2-6), 2.69 (2H, t, J = 7.2, CH_3CH_2-6), 2.83 (3H, s, CH_3-4″), 6.82 (1H, s, H-3), 7.65 (5H, m, H-2′, H-3′, H-4′, H-5′, H-6′), 7.80 (1H, s, H-3″), 8.14 (1H, s, H-5), 9.12 (1H, s, H-10).

9-(4-Nitrophenyl)-4-phenyl-6-propionylpyrano[2,3-*f*]chromen-2,8-dione (20). Yield 0.1 g (22.7%), $C_{27}H_{19}NO_6$, mp 272-273°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 0.91 (3H, m, $CH_3CH_2CH_2$-6), 1.52 (2H, m, $CH_3CH_2CH_2$-6), 2.45 (2H, t, J = 7.6, $CH_3CH_2CH_2$-6), 6.39 (1H, s, H-3), 7.43 (1H, s, H-5), 7.56 (5H, m, H-2′, H-3′, H-4′, H-5′, H-6′), 8.08 (2H, d, J = 8.8, H-3″, H-5″), 8.31 (2H, d, J = 8.8, H-2″, H-6″), 8.56 (1H, s, H-10).

9-[4-(3-Nitrophenyl)thiazol-2-yl]-4-phenyl-6-propylpyrano[2,3-*f*]chromen-2,8-dione (21). Yield 0.19 g, (35.4%), $C_{30}H_{20}N_2O_6S$, mp 246-247°C.

PMR spectrum (400 MHz, TFA, δ, ppm, J/Hz): 0.93 (3H, m, $CH_3CH_2CH_2$-6), 1.54 (2H, m, $CH_3CH_2CH_2$-6), 2.48 (2H,

t, J = 7.6, $CH_3CH_2CH_2$-6), 6.81 (1H, s, H-3), 7.63 (5H, m, H-2′, H-3′, H-4′, H-5′, H-6′), 7.64 (1H, s, H-5), 7.96 (1H, t, J = 8, H-5‴), 8.27 (1H, s, H-2‴), 8.30 (1H, d, J = 8, H-6‴), 8.43 (1H, s, H-3‴), 8.61 (1H, d, J = 8, H-4‴), 8.84 (1H, s, H-10).

9-(4-Methylthiazol-2-yl)-4-phenyl-6-propylpyrano[2,3-*f*]chromen-2,8-dione (22). Yield 0.07 g (16.3%), $C_{25}H_{19}NO_4S$, mp 207-208°C.

PMR spectrum (400 MHz, TFA, δ, ppm, J/Hz): 0.96 (3H, m, $CH_3CH_2CH_2$-6), 1.67 (2H, m, $CH_3CH_2CH_2$-6), 2.76 (2H, t, J = 7.6, $CH_3CH_2CH_2$-6), 2.88 (3H, s, CH_3-4″), 6.65 (1H, s, H-3), 7.39 (1H, s, H-5), 7.58 (5H, m, H-2′, H-3′, H-4′, H-5′, H-6′), 7.73 (1H, s, H-3″), 9.19 (1H, s, H-10).

General Method for Preparing 23-25. The appropriate 7-hydroxy-8-formylneoflavone (1 mmol) and ethylcyanoacetate (1 mmol) in alcoholic $NaHCO_3$ (0.05 M) was stirred at room temperature for 3 h, diluted with HCl (0.25 mL), heated for 2 h at 70°C, and cooled. The precipitate was filtered off and crystallized from propan-2-ol.

2,8-Dioxo-4-phenyl-2*H*,8*H*-pyrano[2,3-*f*]chromen-9-carbonitrile (23). Yield 0.15 g (47.6%), $C_{19}H_9NO_4$, mp 296°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 6.42 (1H, s, H-3), 7.30 (1H, d, J = 8.8, H-6), 7.52 (5H, m, H-2′, H-3′, H-4′, H-5′, H-6′), 7.75 (1H, d, J = 8.8, H-5), 8.89 (1H, s, H-10).

6-Ethyl-2,8-dioxo-4-phenyl-2*H*,8*H*-pyrano[2,3-*f*]chromen-9-carbonitrile (24). Yield 0.13 g (37.9%), $C_{21}H_{13}NO_4$, mp 282-283°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 1.09 (3H, m, CH_3CH_2-6), 2.56 (2H, t, J = 7.2, CH_3CH_2-6), 6.41 (1H, s, H-3), 7.32 (1H, d, J = 8.8, H-6), 7.54 (5H, m, H-2′, H-3′, H-4′, H-5′, H-6′), 7.74 (1H, d, J = 8.8, H-5), 8.87 (1H, s, H-10).

2,8-Dioxo-4-phenyl-6-propyl-2*H*,8*H*-pyrano[2,3-*f*]chromen-9-carbonitrile (25). Yield 0.17 g (47.6%), $C_{22}H_{15}NO_4$, mp 267-268°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 0.91 (3H, m, $CH_3CH_2CH_2$-6), 1.52 (2H, m, $CH_3CH_2CH_2$-6), 2.45 (2H, t, J = 7.6, $CH_3CH_2CH_2$-6), 6.42 (1H, s, H-3), 7.31 (1H, d, J = 8.8, H-6), 7.51 (5H, m, H-2′, H-3′, H-4′, H-5′, H-6′), 7.72 (1H, d, J = 8.8, H-5), 8.88 (1H, s, H-10).

General Method for Preparing 26-31. A mixture of hydroxyacylneoflavone **11**, **12**, or **13** (1 mmol), phenylacetylchloride or chloroacetylchloride (2 mmol), and freshly calcined K_2CO_3 (4 mmol) in absolute acetone (20 mL) was stirred at boiling for 6-9 h. The course of the reaction was monitored by TLC. After the reaction was finished the solvent was evaporated in vacuo in a rotary evaporator. The solid was treated with water. The resulting solid was filtered off, washed with water, and crystallized from aqueous methanol.

6-Ethyl-10-methyl-4,9-diphenylpyrano[2,3-*f*]chromen-2,8-dione (26). Yield 0.15 g (36.8%), $C_{27}H_{20}O_4$, mp 232-234°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 1.24 (3H, m, CH_3CH_2-6), 2.67 (3H, s, CH_3-10), 2.82 (2H, t, J = 7.2, CH_3CH_2-6), 6.35 (1H, s, H-3), 7.30 (2H, m, H-2″, H-6″), 7.44 (3H, m, H-3″, H-4″, H-5″), 7.46 (1H, s, H-5), 7.49 (2H, m, H-2′, H-6′), 7.59 (3H, m, H-3′, H-4′, H-5′).

10-Methyl-4,9-diphenyl-6-propylpyrano[2,3-*f*]chromen-2,8-dione (27). Yield 0.18 g (42.7%), $C_{28}H_{22}O_4$, mp 238-239°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 0.98 (3H, m, $CH_3CH_2CH_2$-6), 1.65 (2H, m, $CH_3CH_2CH_2$-6), 2.66 (3H, s, CH_3-10), 2.76 (2H, t, J = 7.6, $CH_3CH_2CH_2$-6), 6.35 (1H, s, H-3), 7.29 (2H, m, H-2″, H-6″), 7.44 (3H, m, H-3″, H-4″, H-5″), 7.46 (1H, s, H-5), 7.49 (2H, m, H-2′, H-6′), 7.59 (3H, m, H-3′, H-4′, H-5′).

9-Chloro-6-ethyl-10-methyl-4-phenylpyrano[2,3-*f*]chromen-2,8-dione (28). Yield 0.12 g (32.8%), $C_{21}H_{15}ClO_4$, mp 137-138°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 1.12 (3H, m, CH_3CH_2-6), 2.62 (2H, t, J = 7.2, CH_3CH_2-6), 2.98 (3H, s, CH_3-10), 6.16 (1H, s, H-3), 7.38 (1H, s, H-5), 7.47 (2H, m, H-2′, H-6′), 7.56 (3H, m, H-3′, H-4′, H-5′).

9-Chloro-10-methyl-4-phenyl-6-propylpyrano[2,3-*f*]chromen-2,8-dione (29). Yield 0.14 g (36.8%), $C_{22}H_{17}ClO_4$, mp 142-143°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 0.89 (3H, m, $CH_3CH_2CH_2$-6), 1.52 (2H, m, $CH_3CH_2CH_2$-6), 2.53 (2H, t, J = 7.6, $CH_3CH_2CH_2$-6), 2.93 (3H, s, CH_3-10), 6.18 (1H, s, H-3), 7.33 (1H, s, H-5), 7.45 (2H, m, H-2′, H-6′), 7.55 (3H, m, H-3′, H-4′, H-5′).

4,10-Dimethyl-3,6-diphenylpyrano[3,2-*g*]chromen-2,8-dione (30). Yield 0.18 g (45.7%), $C_{26}H_{18}O_4$, mp 285-286°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm): 2.15 (3H, s, CH_3-4), 2.52 (3H, s, CH_3-10), 6.38 (1H, s, H-7), 7.25 (2H, m, H-2′, H-6′), 7.43 (3H, m, H-3′, H-4′, H-5′), 7.56 (5H, m, H-2″, H-3″, H-4″, H-5″, H-6″), 7.66 (1H, s, H-5).

3-Chloro-4,10-dimethyl-6-phenylpyrano[3,2-*g*]chromen-2,8-dione (31). Yield 0.16 g (45.4%), $C_{20}H_{13}ClO_4$, mp 207-208°C.

PMR spectrum (400 MHz, DMSO-d_6, δ, ppm, J/Hz): 2.28 (3H, s, CH_3-4), 2.52 (3H, s, CH_3-10), 6.20 (1H, s, H-7), 7.55 (5H, m, H-2′, H-3′, H-4′, H-5′, H-6′), 7.81 (1H, s, H-5).

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