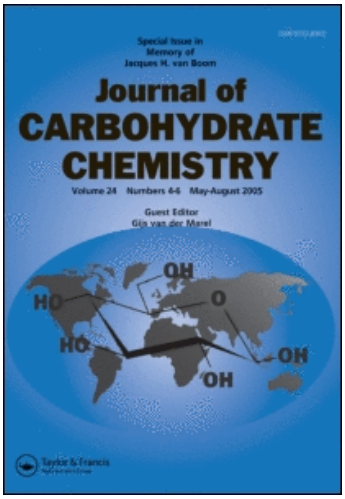


Journal of Carbohydrate Chemistry
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713617200

Synthesis of *O*-β-D-Glucopyranosides of 7-Hydroxy-3-(imidazol-2-yl)-4*H*-chromen-4-ones

V. N. Ingle[a]; K. M. Hatzade[a]; V. S. Taile[a]; P. K. Gaidhane[a]; S. T. Kharche[a]
[a] Department of Chemistry, Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur, India

To cite this Article Ingle, V. N. , Hatzade, K. M. , Taile, V. S. , Gaidhane, P. K. and Kharche, S. T.(2007) 'Synthesis of *O*-β-D-Glucopyranosides of 7-Hydroxy-3-(imidazol-2-yl)-4*H*-chromen-4-ones', Journal of Carbohydrate Chemistry, 26: 2, 107 — 123
To link to this Article: DOI: 10.1080/07328300701298196
URL: http://dx.doi.org/10.1080/07328300701298196

Journal of Carbohydrate Chemistry, 26:107–123, 2007

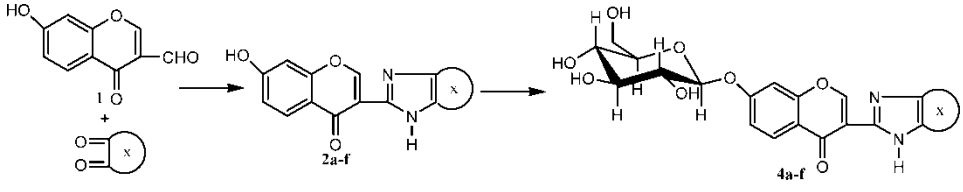
ISSN: 0732-8303 print 1532-2327 online
DOI: 10.1080/07328300701298196

Synthesis of *O*-β-D-Glucopyranosides of 7-Hydroxy-3-(imidazol-2-yl)-4*H*-chromen-4-ones

V. N. Ingle, K. M. Hatzade, V. S. Taile, P. K. Gaidhane, and S. T. Kharche

Department of Chemistry, Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur, India

The 7-hydroxy-3-formyl-4*H*-chromen-4-one **1** reacted with various cyclic 1,2-dicarbonyl compounds in the presence of ammonium acetate to furnish 7-hydroxy-3-([4,5-fused] imidazol-2-yl)-4*H*-chromen-4-ones **2a**–**f**, which on glucosylation with α-acetobromoglucose affords 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyloxy-3-([4,5-fused] imidazol-2-yl)-4H-chromen-4-ones **3a**–**f**. 7-*O*-β-D-Glucopyranosyloxy-3-([4,5-fused] imidazol-2-yl)-4H-chromen-4-ones **4a**–**f** were prepared by deacetylation with anhydrous zinc acetate in absolute methanol. The structure of these new *O*-β-D-glucosides was established on the basis of chemical, elemental, and spectral analysis. These compounds were evaluated for their *in vitro* biological activity.



Keywords Chromone, Imidazoles, α-Acetobromoglucose, Glucosylation, *O*-β-D-Glucosides

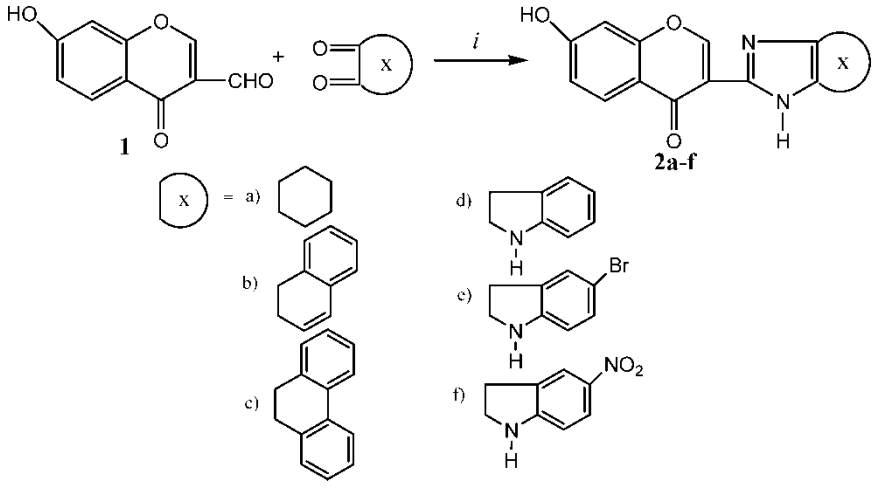
Received February 8, 2007; accepted February 23, 2007.
Address correspondence to K. M. Hatzade, Department of Chemistry, Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur 440033, India. E-mail: g_kishor2000@yahoo.co.in

INTRODUCTION

Fused heterocyclic compounds are common in nature, and they are also used as drugs to treat a wide variety of illness.[1] The fused-ring heterocycles have generally similar properties to those of the simple heterocycles (e.g., benzimidazole exhibiting diverse pharmaceutical and industrial applications). They are found to possess anthelmintic, insecticidal, antibacterial, antiviral, antiamoebic antifungal, antiparasitic, and antihistamine activities.[2–6] On the other hand, flavonoids are based on the flavone and related ring systems and constitute an important class of widely distributed plant secondary metabolites. In addition to the various functions of flavonoids in plants, several therapeutically interesting biological activities of certain flavonoids have been reported including anticancer, anti-HIV, and antioxidant properties,[7] and insect antifeedant activity.[8] Similarly, carbohydrates are being considered as extremely useful stereochemical building blocks for complex organic synthesis. Glycoconjugates exert important roles in many biological processes,[9–11] including particularly cellular recognition in the case of immune response,[12,13] tumor metastasis,[14] inflammation,[15–17] and bacterial and viral infections.[9] The great importance of this category of heterocycles and glycoconjugates and in continuation of our research work on chromone-based heterocycles and their O-β-D-glucosides oriented our attention to the synthesis of a series of new heterocyclic derivatives combining chromone, fused imidazole, and glucose residue in one molecular frame as new possible biological active compounds. Herein we report the synthesis and biological activity of chromones bearing a fused imidazole ring at position 3 and carbohydrate moiety at position 7, starting from the 7-hydroxy-3-formyl-4*H*-chromen-4-one.

RESULTS AND DISCUSSION

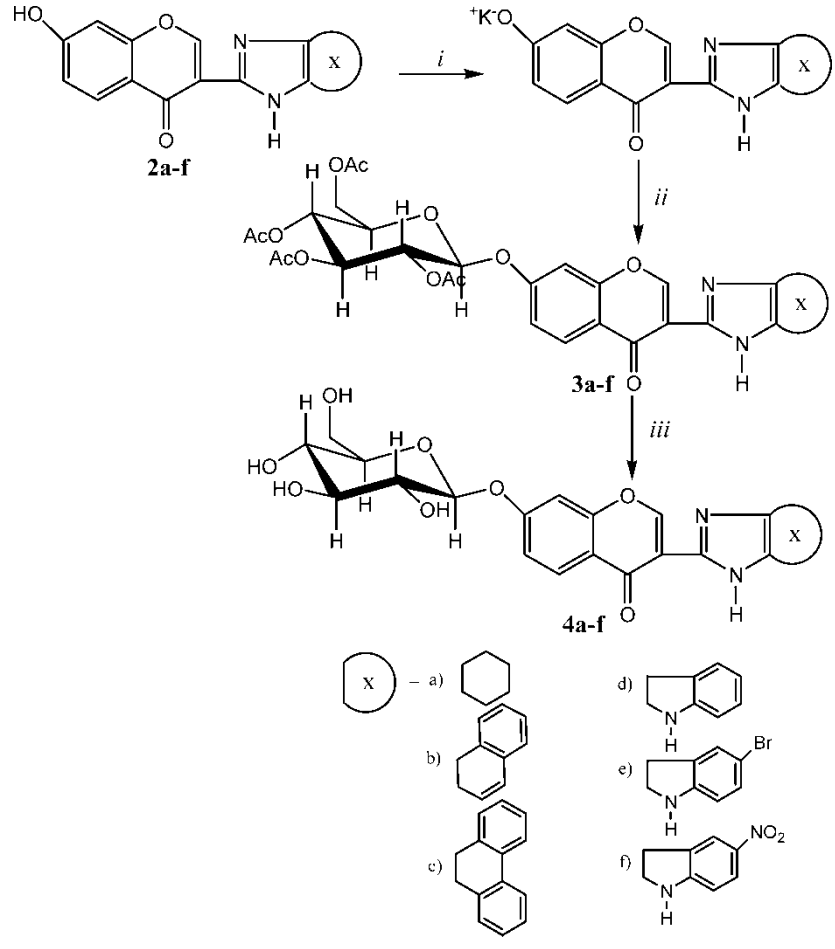
During the course of our present investigation, the starting material, namely, 7-hydroxy-3-formyl-4*H*-chromen-4-one **1**, was prepared from resacetophenone according to the method described previously.[18] This compound **1** on condensation[19] with various cyclic 1,2-dicarbonyl compounds like 1,2-cyclohexadione, 1,2-naphthoquinone, 9,10-phenanthroquinone, etc., in the presence of ammonium acetate in glacial acetic acid leads to the formation of 7-hydroxy-3-([4,5-fused] imidazol-2-yl)-4*H*-chromen-4-ones **2a**–**f**. The IR spectrum of **2a** showed a broad peak at 3451 cm^{-1} due to the OH stretch. The peaks at 2958 and 2361 cm^{-1} appeared due to NH and Ar-CH stretches, respectively. A strong absorption at 1626 cm^{-1} was assigned to C=O stretch. The peaks at 1458 and 1102 cm^{-1} were due to C=N and C-O-C ether linkage stretches, respectively. The ^{1}H NMR spectrum of the said compound showed the peaks at δ 1.58 (m, 5′-2H, 6′-2H) (CH_2), 2.46 (t, 4′-2H, 7′-2H) (CH_2), 5.00 (s, 1H, -OH), 6.34–7.51 (m, 3H, Ar-H), 7.60 (s, 2-H, CH) and 11.2 (s, 1′-H, N-H).



Scheme 1: Synthesis of 7-hydroxy-3-([4, 5-fused) imidazol-2-yl)-4*H*-chromen-4-ones 2; *(i)* CH_3COONH_4, CH_3COOH.

There was no peak due to -CHO group (Sch. 1). ^{13}C NMR data also supported the assigned structure.

α-Acetobromoglucose acts as a glucosyl donor for the glucosylation and was synthesized from pentacetylated derivative of glucose by a known method. Glucosylation[20] of potassium salt of **2a–f** has been carried out using α-acetobromoglucose under argon atmosphere in anhydrous acetonitrile in the presence of 18-crown-6 ether as a catalyst and afforded 2, 3, 4, 6-tetra-*O*-acetyl-7-O-β-D-glucopyranosyloxy-3-([4,5-fused] imidazol-2-yl)-4*H*-chromen-4-ones **3a–f** in high yield. The absence of an IR band at 3100–3500 cm^{-1} (due to OH stretch) indicated the formation of product **3a**. Further, the peaks at 2954 and 2363 cm^{-1} were due to the NH and Ar-CH stretches. The C=O stretch peak was found to be shifted to 1721 cm^{-1}. A strong absorption at 1760 cm^{-1} was assigned to the C=O stretch of *O*-acetyl groups of glucose moiety. The peak at 1051 cm^{-1} was attributed to the C-O-C stretch. A sharp peak at 2854 cm^{-1} was assigned to glucosidic CH stretch. In particular, in the ^1H NMR spectrum of **3a**, the anomeric proton H-1 appeared as a doublet at δ 4.76 with a coupling of ($J_{1,2} = 7.9$ Hz). This relatively large coupling constant is characteristic for a β-D-glucopyranoside. Similarly, ^{13}C data of the acetylated β-glucosides **3a–f** were in agreement with the assigned structures. We tried to deacetylate **3a–f** by standard procedure using NaOMe-MeOH;[21] however, we found that the strong basic condition resulted in cleavage of the isoflavone's C-ring, while the $Zn(OAc)_2$/MeOH system led to significant deglycosylation. Finally, complete deacetylation of **3a–f** was achieved by using anhydrous $Zn(OAc)_2$ in methanol[22] in good yield (Sch. 2). The IR spectrum of **4a** showed the presence of characteristic absorption



Scheme 2: Synthesis of 7-*O*-β-D-glucopyranosyloxy-3-((4,5-fused) imidazol-2-yl)-4*H*-chromen-4-ones 4; *(i)* K_2CO_3, CH_3CN, Ar atmosphere; *(ii)* α-acetobromoglucose, 18-crown-6; *(iii)* $Zn(CH_3COO)_2$, MeOH.

peaks at 3412 (br, OH peak of carbohydrate residue), 2928 (NH), 2853 (glucosidic-CH), 2362 (Ar-CH), 1599 (C=O), 1445 (C=N), and 1089 (C-O-C) cm^{-1}, indicating the formation *O*-β-D-glucoside. This was also confirmed by its ^1H NMR, ^{13}C NMR, and EI-MS data. The ^1H and ^{13}C NMR data show the presence of carbohydrate moiety. The chemical shifts of the anomeric proton show β-linkage at δ 5.74 ($J_{1,2} = 8.4$ Hz), indicating the linkage of the carbohydrate unit to the C-7 position of the aglycone. Compound **4a** exhibited NH at δ 11.2 ppm, aromatic protons at δ 6.36–7.49, and the characteristic pyranosyl ring protons at δ 3.44–4.72. In the EI-MS study, the molecular ion peak at m/z 445 $[M + 1]^+$ was dominated by m/z 282 (100%) with the loss of 163 amu corresponding to the loss of an intact anhydro-sugar moiety. Also, the

molecular ion at m/z 445 $[M + 1]^+$ confirms the molecular formula of the corresponding glucoside. All the compounds gave satisfactory C, H, and N analysis.

BIOLOGICAL RESULTS

Antimicrobial activities of the prepared compounds were tested against bacteria, such as *Escherichia coli, Klebisilla aerogens, Staphylococcus aureus, Bacillus substilis* and fungi, *Aspergillus niger* and *Candida albicans* using the cup plate diffusion method. Ciprofloxacin and sulphacetamide for bacteria and gentamycin and clotrimazole for fungi were used as reference drugs. The results of tested compounds against bacteria and fungi are shown in Table 1.

As shown in Table 1, the glucosides had higher antimicrobial activity against Gram-positive and Gram-negative bacteria and fungi than that of aglycones. The results of antibacterial activities indicated that slight difference between the activities of all the glucosides against tested bacteria. The compounds **4a**–**f** showed very high antibacterial activity against this bacterium. Similarly, the results of antifungal activity revealed that the glucosides had promising antifungal activities against two yeast strains (*C. albicans* and *A. niger*). These results suggested that glucosides had effective and selective antimicrobial activities against both bacteria and fungi.

Table 1 also summarizes free radical scavenging activity (antioxidant activity) using the DPPH assay method. According these results, the newly synthesized glucosides had more promising antioxidant activities.

CONCLUSION

In conclusion, the condensation of 7-hydroxy-3-formyl-4*H*-chromen-4-one with various cyclic 1,2-dicarbonyl compounds in the presence of ammonium acetate followed by glucosydation with α-acetobromoglucose as a glucosyl donor afforded 7-*O*-β-D-glucopyranosyloxy-3-([4,5-fused] imidazol-2-yl)-4*H*-chromen-4-ones **4a**–**f** in quite good yield. These synthesized compounds were evaluated in vitro antimicrobial activity and antioxidant activity. According to the in vitro results, the new glucosides of 7-hydroxy-3-imidazolyl chromones had commonly of greater pharmacological significance. The compounds **4a**–**f** might be promising candidates of new antibacterial as well as antioxidant agents.

EXPERIMENTAL

General

FT-IR spectra were recorded on a Perkin-Elmer spectrum Rx-I spectrophotometer. ^{1}H NMR and ^{13}C NMR spectra were obtained on a Bruker II-400

Table 1: Data for *in vitro* antimicrobial and antioxidant activity of compounds **4a**–**f**.

	Diameter of zone of inhibition (mm) (activity index)[std]						
	Antibacterial			Antifungal			% Inhibition antioxidant
Compd	***S. aureus***	***B. substilis***	***E. coli***	***K. aerogens***	***C. albicans***	***A. niger***	**DPPH**
2a	22 (0.67)[a] (0.71)[b]	22 (0.76)[a] (0.85)[b]	19 (0.54)[a] (0.65)[b]	18 (0.82)[a] (0.86)[b]	28 (1.33)[a] (1.22)[b]	20 (0.80)[a] (0.83)[b]	81.15 (0.83)[a]
2b	20 (0.59)[a] (0.64)[b]	21 (0.72)[a] (0.81)[b]	20 (0.57)[a] (0.69)[b]	18 (0.82)[a] (0.86)[b]	25 (1.19)[a] (1.09)[b]	19 (0.76)[a] (0.79)[b]	81.11 (0.83)[a]
2c	21 (0.62)[a] (0.68)[b]	20 (0.69)[a] (0.77)[b]	21 (0.60)[a] (0.72)[b]	18 (0.82)[a] (0.86)[b]	29 (1.38)[a] (1.26)[b]	21 (0.84)[a] (0.88)[b]	77.52 (0.79)[a]
2d	18 (0.53)[a] (0.58)[b]	18 (0.62)[a] (0.69)[b]	20 (0.57)[a] (0.69)[b]	15 (0.68)[a] (0.71)[b]	29 (1.38)[a] (1.26)[b]	14 (0.56)[a] (0.58)[b]	86.44 (0.88)[a]
2e	20 (0.59)[a] (0.64)[b]	19 (0.66)[a] (0.73)[b]	21 (0.60)[a] (0.72)[b]	19 (0.86)[a] (0.90)[b]	29 (1.38)[a] (1.26)[b]	17 (0.68)[a] (0.71)[b]	75.67 (0.77)[a]
2f	17 (0.50)[a] (0.55)[b]	20 (0.69)[a] (0.77)[b]	24 (0.69)[a] (0.83)[b]	16 (0.77)[a] (0.81)[b]	22 (1.05)[a] (0.96)[b]	22 (0.88)[a] (0.92)[b]	75.82 (0.77)[a]
4a	25 (0.74)[a] (0.81)[b]	34 (1.17)[a] (1.31)[b]	20 (0.57)[a] (0.69)[b]	20 (0.91)[a] (0.95)[b]	31 (1.48)[a] (1.35)[b]	21 (0.84)[a] (0.88)[b]	84.45 (0.86)[a]
4b	29 (0.85)[a] (0.94)[b]	24 (0.83)[a] (0.92)[b]	21 (0.60)[a] (0.72)[b]	19 (0.86)[a] (0.90)[b]	30 (1.43)[a] (1.30)[b]	22 (0.88)[a] (0.92)[b]	78.12 (0.80)[a]
4c	28 (0.82)[a] (0.90)[b]	37 (1.28)[a] (1.42)[b]	24 (0.69)[a] (0.83)[b]	24 (1.09)[a] (1.14)[b]	34 (1.62)[a] (1.48)[b]	23 (0.92)[a] (0.96)[b]	89.25 (0.91)[a]
4d	20 (0.59)[a] (0.65)[b]	23 (0.79)[a] (0.88)[b]	22 (0.63)[a] (0.76)[b]	17 (0.77)[a] (0.81)[b]	36 (1.71)[a] (1.57)[b]	22 (0.88)[a] (0.92)[b]	80.78 (0.82)[a]
4e	23 (0.68)[a] (0.74)[b]	17 (0.59)[a] (0.65)[b]	35 (1.00)[a] (1.21)[b]	20 (0.91)[a] (0.95)[b]	32 (1.52)[a] (1.39)[b]	21 (0.84)[a] (0.88)[b]	81.01 (0.83)[a]
4f	19 (0.56)[a] (0.61)[b]	25 (0.86)[a] (0.96)[b]	33 (0.94)[a] (1.14)[b]	17 (0.77)[a] (0.81)[b]	25 (1.19)[a] (1.09)[b]	23 (0.92)[a] (0.96)[b]	78.25 (0.80)[a]
Std.1	34	29	35	22	21	25	98.03
Std. 2	31	26	29	21	23	24	

(Activity index) = Inhibition zone of the sample/inhibition zone of the standard.
[a]Activity index against std. 1.
[b]Activity index against std. 2.
For antibacterial activity: Std. 1 = ciprofloxacin and Std. 2 = sulphacetamide. For antifungal activity: Std. 1 = gentamycin and Std. 2 = clotrimazole. For antioxidant activity: Std. 1= ascorbic acid.

NMR spectrophotometer (^{1}H, 400 MHz and ^{13}C, 100 MHz), using TMS as an internal standard in DMSO-d_6, Chemical shifts (δ) were measured in ppm. Multiplicity was simplified such as s = singlet, d = doublet, t = triplet, and m = multiplet. Mass spectra were determined on a Hitachi Perkin-Elmer RMU 6D mass spectrometer. Optical rotations were recorded at the sodium D line and ambient temperature with a JASCO digital polarimeter. Elemental analyses were performed on a Perkin-Elmer 2400 CHN analyzer instrument. Purity of the compounds was checked on silica gel plates using iodine vapor as a visualizing agent. Melting points measured in open capillary tubes were uncorrected. The solvents and various essential reagents were purified and dried according to recommended procedures. Various cyclic 1,2-dicarbonyl compounds like 1,2-cyclohexadione, 1,2-naphthoquinone, and 9,10-phenanthrenquinone were prepared according to the method described previously.[23,24]

7-Hydroxy-3-formyl-4*H*-chromen-4-one (1)

In dry DMF (121 mL) in a three-necked flask, $POCl_3$ (75 mL, 0.49 mol) was added slowly with vigorous stirring at 50°C. Heating and stirring was continued for 2 h at 45–55°C. The solution of resacetophenone (18.24 g, 0.12 mol) in DMF (25 mL) was then slowly added with stirring at 50°C and the stirring was continued for 2 h. After cooling, the mixture was kept overnight at rt and diluted slowly by adding ice-cold water (500 mL) and stirred again for 6 h. The red crystalline product obtained was filtered off and recrystallized from alcohol, m.p. 269°C, yield 45 g (78%). Its alcoholic solution gives violet coloration with neutral $FeCl_3$. IR (KBr): υ 3428 (phenolic OH), 3087, 2363 (Ar-CH), 2773 (CH in CHO), 1685 (C=O), 1614 (C=C), 1093 (C-O-C) cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ 4.95 (s, 1H, -OH), 6.35–7.5 (m, 3H, Ar-H), 8.05 (s, 2-H, CH), 9.59 (s, 1H, CHO); ^{13}C NMR (100 MHz, DMSO-d_6): 104.8 (s, C-8), 109.4 (s, C-6), 114.0 (s, C-10), 121.7 (s, C-3, C-CHO), 131.4 (s, C-5), 157.9 (s, C-9), 161.2 (s, C-7), 171.0 (s, C-2), 174.9 (s, C-4, C=O), 188.1 (s, CHO of C-3).

General Procedure for the Preparation of 7-Hydroxy-3-((4, 5-fused) imidazol-2-yl)-4*H*-chromen-4-ones (2)

A mixture of 7-hydroxy-3-formyl-4*H*-chromen-4-one (5 mmol), cyclic 1, 2-dicarbonyl compounds (5 mmol), ammonium acetate (10 mmol), and glacial acetic acid (50 mL) was refluxed for 2 h. It was poured in to cold water (200 mL). The solid obtained was filtered, washed with water, and crystallized from solvents.

7-Hydroxy-3-(4,5,6,7-tetrahydro-1H-benzo[d]imidazol-2-yl)-4H-chromen-4-one (2a)

Yield 67%; mp 295°C (ethanol); IR (KBr): 3451 (br, OH), 2958 (NH), 1625 (C═O), 1457 (C═N), 1102 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): δ 1.58 (m, 5′-2H, 6′-2H) (CH_2), 2.46 (t, 4′-2H, 7′-2H) (CH_2), 5.00 (s, 1H, OH), 6.34–7.51 (m, 3H, Ar-H), 7.60 (s, 2-H, CH), 11.2 (s, 1′-H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): 20.1 (s, C-5′, C-6′), 26.9 (s, C-4′, C-7′), 104.0 (s, C-8), 111.8 (s, C-6), 115.1 (s, C-10), 118.6 (s, C-3), 124.8 (s, C-8′, C-9′), 132.0 (s, C-5), 135.7 (s, C-2′), 158.7 (s, C-9), 159.3 (s, C-2), 163.5 (s, C-7), 175.8 (s, C-4, C═O); MS (EI, 70 eV): m/z (%) 282 (M^+, 100), 161 (19), 91 (28).

Anal. Calcd. for $C_{16}H_{14}N_2O_3$ (282): C, 68.07; H, 5.00; N, 9.92. Found: C, 68.06; H, 4.95; N, 9.91.

7-Hydroxy-3-(3H-naphtho[2,1-d]imidazol-2-yl)-4H-chromen-4-one (2b)

Yield 76%; mp 299°C (chloroform + dioxane); IR (KBr): 3400(br, OH), 2989 (NH), 1627 (C═O), 1458 (C═N), 1103 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): δ 4.95 (s, 1H, OH), 6.35–7.75 (m, 9H, Ar-H), 7.52 (s, 2-H, CH), 12.3 (s, 1′-H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): 105.5 (s, C-8), 110.1 (s, C-6), 114.9 (s, C-9′), 115.0 (s, C-12′), 116.2 (s, C-10), 118.9 (s, C-3), 123.1 (s, C-13′), 123.4 (s, C-8′), 127.1 (s, C-4′, C-7′), 127.9 (s, C-5′, C-6′), 131.0 (s, C-5), 139.1 (s, C-10′), 141.4 (s, C-2′), 142.1 (s, C-11′), 157.8 (s, C-9), 158.9 (s, C-2), 164.5 (s, C-7), 176.1 (s, C-4, C═O); MS (EI, 70 eV): m/z (%) 328 (M^+, 100), 161 (22), 91 (29).

Anal. Calcd. for $C_{20}H_{12}N_2O_3$ (328): C, 73.14; H, 3.67; N, 8.52. Found: C, 73.16; H, 3.68; N, 8.53.

7-Hydroxy-3-(1H-phenanthro[9,10-d]imidazol-2-yl)-4H-chromen-4-one (2c)

Yield 80%; mp 326°C (ethanol); IR (KBr): 3429 (br, OH), 2925 (NH), 2361 (Ar-CH), 1624 (C═O), 1506 (C═N), 1095 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): δ 5.02 (s, 1H, OH), 6.37–9.01 (m, 11H, Ar-H), 7.50 (s, 2-H, CH), 11.2 (s, 1′-H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): 104.8 (s, C-8), 110.1 (s, C-6), 115.9 (s, C-10), 117.6 (s, C-3), 123.1 (s, C-7′, C-8′), 126.4 (s, C-5′, C-6′, C-9′, C-10′), 126.8 (s, C-13′, C-14′), 127.7 (s, C-12′, C-15′), 128.8 (s, C-4′, C-11′), 131.6 (s, C-16′, C-17′), 131.9 (s, C-5), 141.0 (s, C-2′), 157.5 (s, C-9), 160.0 (s, C-2), 165.1 (s, C-7), 174.8 (s, C-4, C═O); MS (EI, 70 eV): m/z (%) 378 (M^+, 100), 217 (27), 163 (44), 91 (29).

Anal. Calcd. for $C_{24}H_{14}N_2O_3$ (378): C, 76.18; H, 3.73; N, 7.40. Found: C, 76.15; H, 3.71; N, 7.38.

3-(3,4,-Dihydroimidazo[4,5-b]indol-2-yl)-7-hydroxy-4H-chromen-4-one (2d)

Yield 79%; mp 315°C (chloroform + dioxane); IR (KBr): 3412 (br, OH), 2986 (NH), 1631 (C═O), 1456 (C═N), 1160 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): δ 4.94 (s, 1H, OH), 6.29–7.55 (m, 7H, Ar-H), 7.57 (s, 2-H, CH), 10.7 (s, 8′-H, NH), 11.8 (s, 1′-H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): 106.1 (s, C-8), 109.8 (s, C-6), 110.9 (s, C-7′), 117.0 (s, C-10), 117.9 (s, C-3), 118.8 (s, C-4′), 120.2 (s, C-6′), 120.5 (s, C-11′), 122.0 (s, C-5′), 133.1 (s, C-5), 135.1 (s, C-12′), 135.9 (s, C-2′), 136.2 (s, C-10′), 143.0 (s, C-9′), 157.9 (s, C-9), 159.4 (s, C-2), 164.9 (s, C-7), 175.2 (s, C-4, C═O); MS (EI, 70 eV): m/z (%) 317 (M^+, 100), 161 (27), 91 (29).

Anal. Calcd. for $C_{18}H_{11}N_3O_3$ (317): C, 68.14; H, 3.49; N, 13.24. Found: C, 68.12; H, 3.48; N, 13.23.

3-(7-Bromo-3,4,-dihydroimidazo[4,5-b]indol-2-yl)-7-hydroxy-4H-chromen-4-one (2e)

Yield 68%; mp 296°C (chloroform + dioxane); IR (KBr): 3447 (br, OH), 2995 (NH), 1621 (C═O), 1457 (C═N), 1154 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): δ 4.94 (s, 1H, OH), 6.35–7.75 (m, 6H, Ar-H), 7.57 (s, 2-H, CH), 10.0 (s, 8′-H, NH), 11.2 (s, 1′-H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): 106.1 (s, C-8), 109.8 (s, C-6), 113.0 (s, C-7′), 117.0 (s, C-10), 117.2 (s, C-5′), 117.9 (s, C-3), 120.8 (s, C-4′), 121.0 (s, C-6′), 122.2 (s, C-11′), 133.1 (s, C-5), 134.1 (s, C-12′), 135.8 (s, C-2′), 136.8 (s, C-10′), 143.2 (s, C-9′), 157.9 (s, C-9), 159.4 (s, C-2), 164.9 (s, C-7), 175.2 (s, C-4, C═O).

Anal. Calcd. for $C_{18}H_{10}BrN_3O_3$ (396): C, 54.17; H, 2.54; N, 10.61. Found: C, 54.16; H, 2.52; N, 10.60.

7-Hydroxy-3-(7-nitro-3,4,-dihydroimidazo[4,5-b]indol-2-yl)-4H-chromen-4-one (2f)

Yield 65%; mp 305°C (ethanol); IR (KBr): 3443 (br, OH), 2987 (NH), 1624 (C═O), 1452 (C═N), 1166 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): δ 4.94 (s, 1H, OH), 6.38–8.50 (m, 6H, Ar-H), 7.57 (s, 2-H, CH), 9.10 (s, 8′-H, NH), 11.8 (s, 1′-H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): 106.1 (s, C-8), 109.8 (s, C-6), 112.2 (s, C-7′), 114.1 (s, C-6′), 115.8 (s, C-4′), 117.0 (s, C-10), 117.9 (s, C-3), 121.5 (s, C-11′), 133.1 (s, C-5), 135.4 (s, C-2′), 135.9 (s, C-10′), 141.0 (s, C-5′), 141.8 (s, C-12′), 142.0 (s, C-9′), 157.9 (s, C-9), 159.4 (s, C-2), 164.9 (s, C-7), 175.2 (s, C-4, C═O).

Anal. Calcd. for $C_{18}H_{10}N_4O_5$ (362): C, 59.67; H, 2.78; N, 15.46. Found: C, 59.68; H, 2.80; N, 15.14.

General Procedure for the Preparation of 2,3,4,6-Tetra-*O*-acetyl-7-*O*-β-D-glucopyranosyloxy-3-((4,5-fused) imidazol-2-yl)-4*H*-chromen-4-ones (3)

A mixture of 7-hydroxy-3-([4, 5-fused] imidazol-2-yl)-4*H*-chromen-4-ones (0.39 mmol), K_2CO_3 (0.43 mmol), and acetonitrile (50 mL) was stirred at rt under argon atmosphere. 18-Crown-6 (10 mg, 0.04 mmol) was added followed by α-acetobromoglucose (0.245 g, 0.58 mmol). After 5 h, it was poured into ice cold water and neutralized with H_2SO_4 (1 mol/L). The product was extracted in ethyl acetate (50 mL × 4). Removal of the volatiles under reduced pressure afforded residue was purified by silica gel flash chromatography (ethyl acetate:petroleum ether 1:2 v/v) to give a brown coloured semisolid.

2,3,4,6-Tetra-O-acetyl-7-O-β-D-glucopyranosyloxy-3-(4,5,6,7-tetrahydro-1H-benzo[d]imidazol-2-yl)-4H-chromen-4-one (3a)

Yield 79%; $[\alpha]_D^{25} = -7.9$ (*c* 0.1, CH_3OH); IR (KBr): 2954 (NH), 2854 (glucosidic CH), 2365 (Ar-CH), 1761 (C═O of *O*-acetyl gps of glycone moiety), 1722 (C═O), 1646 (C═N), 1052 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): δ 1.59 (m, 5′-2H, 6′-2H) (CH_2), 2.01, 1.95, 1.99, 2.05 (s, 3H, OAc), 2.58 (t, 4′-2H, 7′-2H) (CH_2), 3.86–4.24 (m, 2H, 6″-H), 4.39 (dd, 1H, 5″-H), 4.76 (d, 1H, 1″-H, anomeric proton), 4.87–5.00 (m, 3H, 2″,3″,4″-H), 6.38–7.49 (m, 3H, Ar-H), 7.51 (s, 2-H, CH), 11.8 (s, 1′-H, N-H); ^{13}C NMR (100 MHz, DMSO-d_6): 21.8 (s, C-atom, CH_3 of Acetyl group), 22.4 (s, C-5′, C-6′), 25.8 (s, C-4′, C-7′), 66.1 (s, C-6″), 71.1 (s, C-3″), 71.5 (s, C-4″), 72.8 (s, C-2″), 74.9 (s, C-5″), 101.9 (s, C-1″, anomeric C-atom), 103.9 (s, C-8), 109.1 (s, C-6), 115.6 (s, C-10), 118.2 (s, C-3), 125.1 (s, C-8′, C-9′), 131.2 (s, C-5), 135.5 (s, C-2′), 157.9 (s, C-9), 159.8 (s, C-2), 163.9 (s, C-7), 171.0 (s, C-atoms of Acetyl C═O), 174.9 (s, C-4, C═O).

Anal. Calcd. for $C_{30}H_{32}N_2O_{12}$ (613): C, 58.82; H, 5.27; N, 4.57. Found: C, 58.90; H, 5.26; N, 4.55.

2,3,4,6-Tetra-O-acetyl-7-O-β-D-glucopyranosyloxy-3-(3H-naphtho [2,1-d] imidazol-2-yl)-4H-chromen-4-one (3b)

Yield 88%; $[\alpha]_D^{25} = -6.0$ (*c* 0.1, CH_3OH); IR (KBr): 2935 (NH), 2882 (glucosidic CH), 2364 (Ar-CH), 1758 (C═O of O-acetyl gps of glycone moiety), 1727 (C═O), 1624 (C═N), 1055 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.02, 1.96, 1.98, 2.04 (s, 3H, OAc), 3.90–4.21 (2H, m, 6″-H), 4.40 (1H, dd, 5″-H), 4.71 (1H, d, 1″-H, anomeric proton), 4.85–5.04 (3H, m, 2″,3″,4″-H), 6.34–7.72 (m, 9H, Ar-H), 7.53 (s, 2-H, CH), 11.6 (s, 1′-H, N-H); ^{13}C NMR (100 MHz, DMSO-d_6): 20.5 (s, C-atom, CH_3 of Acetyl group), 66.0 (s, C-6″), 71.0 (s, C-4″), 71.5 (s, C-3″), 72.2 (s, C-2″), 75.5 (s, C-5″), 102.8 (s, C-1″, anomeric C-atom), 104.1 (s, C-8), 108.1 (s, C-6), 115.1 (s, C-10), 114.8 (s, C-9′), 115.8 (s, C-12′), 117.8 (s, C-3), 122.4 (s, C-13′), 124.5 (s, C-8′), 127.0 (s, C-4′, C-7′), 127.5

(s, C-5′, C-6′), 130.8 (s, C-5), 139.1 (s, C-10′), 141.2 (s, C-2′), 142.0 (s, C-11′), 158.0 (s, C-9), 159.0 (s, C-2), 164.7 (s, C-7), 170.5 (s, C-atoms of Acetyl C═O), 176.0 (s, C-4, C═O).

Anal. Calcd. for $C_{34}H_{30}N_2O_{12}$ (659): C, 62.00; H, 4.59; N, 4.25. Found: C, 62.01; H, 4.58; N, 4.23.

2,3,4,6-Tetra-O-acetyl-7-O-β-D-glucopyranosyloxy-3-(1H-phenanthro [9,10-d] imidazol-2-yl)-4H-chromen-4-one (3c)

Yield 87%; $[\alpha]_D^{25} = -5.2$ (*c* 0.1, CH_3OH); IR (KBr): 2924 (NH), 2854 (glucosidic CH), 2363 (Ar-CH), 1757 (C═O of *O*-acetyl gps of glycone moiety), 1746 (C═O), 1590 (C═N), 1091 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): 2.02, 1.94, 1.96, 2.01 (s, 3H) ($COCH_3$), 3.81–4.25 (2H, m, 6″-H), 4.45 (1H, dd, 5″-H), 4.79 (1H, d, 1″-H, anomeric proton), 4.84–4.99 (3H, m, 2″,3″,4″-H), 6.38–8.98 (m, 11H, Ar-H), 7.57 (s, 2-H, CH), 11.7 (s, 1′-H, NH); ^{13}C NMR(100 MHz, DMSO-d_6): 22.5 (s, C-atom, CH_3 of Acetyl group), 66.1 (s, C-6″), 71.5 (s, C-4″), 71.7 (s, C-3″), 72.1 (s, C-2″), 75.4 (s, C-5″), 101.9 (s, C-1″, anomeric C-atom), 104.1 (s, C-8), 109.4 (s, C-6), 114.8 (s, C-10), 117.8 (s, C-3), 122.8 (s, C-7′, C-8′), 127.2 (s, C-5′, C-6′, C-9′, C-10′), 127.9 (s, C-13′, C-14′), 128.0 (s, C-12′, C-15′), 128.6 (s, C-4′, C-11′), 131.8 (s, C-16′, C-17′), 131.5 (s, C-5), 141.1 (s, C-2′), 158.0 (s, C-9), 158.9 (s, C-2), 163.8 (s, C-7), 169.9 (s, C-atoms of Acetyl C═O), 176.2 (s, C-4, C═O).

Anal. Calcd. for $C_{38}H_{32}N_2O_{12}$ (708): C, 64.40; H, 4.55; N, 3.95. Found: C, 64.38; H, 4.54; N, 3.93.

3-(3,4,-Dihydroimidazo[4, 5-b]indol-2-yl)-2,3,4,6-tetra-O-acetyl-7-O-β-D-glucopyranosyloxy-4H-chromen-4-one (3d)

Yield 85%; $[\alpha]_D^{25} = -8.1$(c 0.1, CH_3OH); IR (KBr): 2945 (NH), 2855 (glucosidic CH), 2365 (Ar-CH), 1754 (C═O of *O*-acetyl gps of glycone moiety), 1722 (C═O), 1646 (C═N), 1055 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.02, 1.91, 1.99, 2.00 (s, 3H, OAc), 3.89–4.29 (2H, m, 6″-H), 4.41 (1H, dd, 5″-H), 4.79 (1H, d, 1″-H, anomeric proton), 4.86–5.02 (3H, m, 2″,3″,4″-H), 6.33–7.59 (m, 7H, Ar-H), 7.60 (s, 2-H, CH), 10.7 (s, 8′-H, NH), 11.8 (s, 1′-H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): 20.7 (s, C-atom, CH_3 of Acetyl group), 66.1 (s, C-6″), 71.2 (s, C-3″), 71.3 (s, C-4″), 72.1 (s, C-2″), 75.4 (s, C-5″), 102.9 (s, C-1″, anomeric C-atom), 104.3 (s, C-8), 109.9 (s, C-6), 110.2 (s, C-7′), 116.0 (s, C-10), 118.6 (s, C-3), 118.9 (s, C-4′), 120.4 (s, C-6′), 120.9 (s, C-11′), 122.7 (s, C-5′), 131.6 (s, C-5), 135.0 (s, C-12′), 135.7 (s, C-2′), 136.8 (s, C-10′), 143.1 (s, C-9′), 157.1 (s, C-9), 160.2 (s, C-2), 164.1 (s, C-7), 171.0 (s, C-atoms of Acetyl C═O), 175.8 (s, C-4, C═O).

Anal. Calcd. for $C_{32}H_{29}N_3O_{12}$ (648): C, 59.35; H, 4.51; N, 6.49. Found: C, 59.33; H, 4.49; N, 6.49.

3-(7-Bromo-3,4,-dihydroimidazo[4, 5-b]indol-2-yl)-2,3,4,6-tetra-O-acetyl-7-O-β-D-glucopyranosyloxy-4H-chromen-4-one (3e)

Yield 78%; $[\alpha]_D^{25} = -4.6$ (*c* 0.1, CH_3OH); IR (KBr): 2957 (NH), 2857 (glucosidic CH), 2360 (Ar-CH), 1776 (C═O of *O*-acetyl gps of glycone moiety), 1718 (C═O), 1645 (C═N), 1091 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.01, 2.00, 1.97, 2.01 (s, 3H, OAc), 3.87–4.29 (m, 2H, 6″-H), 4.41 (dd, 1H, 5″-H), 4.78 (d, 1H, 1″-H, anomeric proton), 4.84–5.05 (m, 3H, 2″,3″,4″-H), 6.41–7.77 (m, 6H, Ar-H), 7.57 (s, 2-H, CH), 10.8 (s, 8′-H, NH), 11.3 (s, 1′-H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): 21.4 (s, C-atom, CH_3 of Acetyl group), 66.1 (s, C-6″), 71.1 (s, C-4″), 71.3 (s, C-3″), 71.9 (s, C-2″), 75.1 (s, C-5″), 101.9 (s, C-1″, anomeric C-atom), 103.1 (s, C-8), 109.7 (s, C-6), 113.5 (s, C-7′), 115.9 (s, C-10), 116.8 (s, C-5′), 118.9 (s, C-3), 121.4 (s, C-4′), 121.8 (s, C-6′), 122.0 (s, C-11′), 131.0 (s, C-5), 134.1 (s, C-12′), 135.7 (s, C-2′), 136.2 (s, C-10′), 142.8 (s, C-9′), 157.5 (s, C-9), 158.7 (s, C-2), 164.1 (s, C-7), 170.0 (s, C-atoms of Acetyl C═O), 174.8 (s, C-4, C═O).

Anal. Calcd. for $C_{32}H_{28}BrN_3O_{12}$ (726): C, 52.90; H, 3.88; N, 5.78. Found: C, 52.85; H, 3.85; N, 5.71.

2,3,4,6-Tetra-O-acetyl-7-O-β-D-glucopyranosyloxy-3-(7-nitro-3,4,-dihydroimidazo[4,5-b]indol-2-yl)-4H-chromen-4-one (3f)

Yield 70%; $[\alpha]_D^{25} = -7.7$ (*c* 0.1, CH_3OH); IR (KBr): 2935 (NH), 2859 (glucosidic CH), 2363 (Ar-CH), 1768 (C═O of *O*-acetyl gps of glycone moiety), 1717 (C═O), 1631 (C═N), 1074 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.00, 2.01, 1.98, 2.04 (s, 3H, OAc), 3.84–4.20 (m, 2H, 6″-H), 4.41 (dd, 1H, 5″-H), 4.77 (d, 1H, 1″-H, anomeric proton), 4.81–4.99 (3H, m, 2″,3″,4″-H), 6.40–8.50 (m, 6H, Ar-H), 7.54 (s, 2-H, CH), 10.5 (s, 8′-H, NH), 12.0 (s, 1′-H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): 21.4 (s, C-atom, CH_3 of Acetyl group), 66.0 (s, C-6″), 71.1 (s, C-4″), 71.4 (s, C-3″), 73.1 (s, C-2″), 74.9 (s, C-5″), 101.7 (s, C-1″, anomeric C-atom), 103.4 (s, C-8), 109.8 (s, C-6), 111.7 (s, C-7′), 114.4 (s, C-6′), 115.0 (s, C-4′), 115.8 (s, C-10), 119.0 (s, C-3), 120.6 (s, C-11′), 131.6 (s, C-5), 135.7 (s, C-2′), 136.4 (s, C-10′), 141.0 (s, C-5′), 141.3 (s, C-12′), 142.0 (s, C-9′), 158.2 (s, C-9), 159.0 (s, C-2), 163.7 (s, C-7), 171.0 (s, C-atoms of Acetyl C═O), 175.1 (s, C-4, C═O).

Anal. Calcd. for $C_{32}H_{28}N_4O_{14}$ (693): C, 55.49; H, 4.07; N, 8.09. Found: C, 55.45; H, 4.06; N, 8.08.

General Procedure for the Preparation of 7-*O*-β-D-Glucopyranosyloxy-3-((4,5-fused) imidazol-2-yl)-4*H*-chromen-4-ones (4)

The mixture of 2, 3, 4, 6-tetra-*O*-acetyl-7-*O*-β-D-glucopyranosyloxy -3-([4, 5-fused] imidazol-2-yl)-4*H*-chromen-4-ones (0.109 mmol), dry methanol (2 mL),

and anhydrous zinc acetate (23 mg, 0.126 mmol) was refluxed for 7 h. After cooled down at rt, it was filtered through cation-exchanged resin; the solvent was removed under vacuum. The residue was purified by silica gel chromatography ($CHCl_3$, MeOH, 12:1 v/v) to get the titled compound.

7-O-β-D-Glucopyranosyloxy-3-(4,5,6,7-tetrahydro-1H-benzo[d]imidazol-2-yl)-4H-chromen-4-one (4a)

Yield 77%; $[\alpha]_D^{25} = -20.1$(*c* 0.1, DMSO); IR (KBr): 3412 (br, OH peak of carbohydrate residue), 2929 (NH), 2853 (glucosidic CH), 2363 (Ar-CH), 1599 (C═O), 1445 (C═N), 1089 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): δ 1.57 (m, 5′-2H, 6′-2H) (CH_2), 2.48 (t, 4′-2H, 7′-2H) (CH_2), 3.44–4.72 (m, 6H, β-D-glucopyranosyl ring), 5.74 (d, 1″-H, anomeric proton), 6.36–7.49 (m, 3H, Ar-H), 7.50 (s, 2-H, CH), 11.2 (s, 1′-H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): 21.9 (s, C-5′, C-6′), 25.0 (s, C-4′, C-7′), 64.0 (s, C-6″), 73.1 (s, C-4″), 74.9 (s, C-2″), 77.6 (s, C-3″), 82.1 (s, C-5″), 104.0 (s, C-8), 106.0 (s, C-1″, anomeric C-atom), 109.9 (s, C-6), 116.2 (s, C-10), 118.2 (s, C-3), 124.6 (s, C-8′, C-9′), 130.8 (s, C-5), 135.4 (s, C-2′), 158.1 (s, C-9), 159.6 (s, C-2), 163.8 (s, C-7), 174.7 (s, C-4, C═O); MS (EI, 70 eV): *m/z* (%) 445 (10) $[M + 1]^+$, 282 (100), 163 (25), 161 (18), 91 (30).

Anal. Calcd. for $C_{22}H_{24}N_2O_8$ (444): C, 59.45; H, 5.44; N, 6.30. Found: C, 59.44; H, 5.43; N, 6.31.

7-O-β-D-Glucopyranosyloxy-3-(3H-naphtho[2,1-d]imidazol-2-yl)-4H-chromen-4-one (4b)

Yield 69%; $[\alpha]_D^{25} = -17.6$ (*c* 0.1, DMSO); IR (KBr): 3446 (br, OH peak of carbohydrate residue), 2958 (NH), 2856 (glucosidic CH), 2363 (Ar-CH), 1598 (C═O), 1414 (C═N), 1091 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): δ 3.45–4.95 (m, 6H, β-D-glucopyranosyl ring), 5.69 (d, 1″-H, anomeric proton), 6.41–7.78 (m, 9H, Ar-H), 7.52 (s, 2-H, CH), 12.8 (s, 1′-H, N-H); ^{13}C NMR (100 MHz, DMSO-d_6): 65.8 (s, C-6″), 73.0 (s, C-4″), 75.9 (s, C-2″), 77.7 (s, C-3″), 81.1 (s, C-5″), 103.5 (s, C-8), 105.0 (s, C-1″, anomeric C-atom), 109.3 (s, C-6), 115.1 (s, C-10), 115.3 (s, C-9′), 115.9 (s, C-12′), 118.0 (s, C-3), 123.2 (s, C-13′), 124.2 (s, C-8′), 127.1 (s, C-5′, C-6′), 127.9 (s, C-4′, C-7′), 131.1 (s, C-5), 139.1 (s, C-10′), 141.2 (s, C-2′), 142.1 (s, C-11′), 158.1 (s, C-9), 159.6 (s, C-2), 163.5 (s, C-7), 176.0 (s, C-4, C═O); MS (EI, 70 eV): *m/z* (%) 491 (7) $[M + 1]^+$, 328 (M^+, 100), 163 (18), 161 (15), 91 (19).

Anal. Calcd. for $C_{26}H_{22}N_2O_8$ (490): C, 63.67; H, 4.52; N, 5.71. Found: C, 63.65; H, 4.51; N, 5.88.

7-O-β-D-Glucopyranosyloxy-3-(1H-phenanthro[9,10-d]imidazol-2-yl)-4H-chromen-4-one (4c)

Yield 94%; $[\alpha]_D^{25} = -13.7$ (*c* 0.1, DMSO); IR (KBr): 3400 (br, OH peak of carbohydrate residue), 2925 (NH), 2854 (glucosidic CH), 2363 (Ar-CH), 1592

(C=O), 1404 (C=N), 1071 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): δ 3.41–4.70 (m, 6H, β-D-glucopyranosyl ring), 5.85 (d, 1″-H, anomeric proton), 6.40–8.90 (m, 11H, Ar-H), 7.49 (s, 2-H, CH), 12.0 (s, 1′-H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): 65.7 (s, C-6″), 73.9 (s, C-4″), 75.1 (s, C-2″), 77.0 (s, C-3″), 81.2 (s, C-5″), 103.1 (s, C-8), 105.4 (s, C-1″, anomeric C-atom), 109.1 (s, C-6), 114.9 (s, C-10), 119.4 (s, C-3), 122.0 (s, C-7′, C-8′), 126.1 (s, C-5′, C-6′, C-9′, C-10′), 126.8 (s, C-13′, C-14′), 127.9 (s, C-12′, C-15′), 128.4 (s, C-4′, C-11′), 131.0 (s, C-5), 131.1 (s, C-16′, C-17′), 142.1 (s, C-2′), 157.7 (s, C-9), 159.1 (s, C-2), 164.7 (s, C-7), 176.2 (s, C-4, C=O); MS (EI, 70 eV): m/z (%) 541 (13) $[M+1]^+$, 378 (100), 217 (13), 163 (40), 161 (20), 91 (11).

Anal. Calcd. for $C_{30}H_{24}N_2O_8$ (540): C, 66.66; H, 4.48; N, 5.18. Found: C, 66.65; H, 4.47; N, 5.16.

3-(3,4,-Dihydroimidazo[4,5-b]indol-2-yl)-7-O-β-D-glucopyranosyloxy-4H-chromen-4-one (4d)

Yield 80%; $[\alpha]_D^{25} = -15.3$ (c 0.1, DMSO); IR (KBr): 3428 (br, OH peak of carbohydrate residue), 2929 (NH), 2858 (glucosidic CH), 2363 (Ar-CH), 1597 (C=O), 1429 (C=N), 1100 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): δ 3.43–4.78 (m, 6H, β-D-glucopyranosyl ring), 5.80 (d, 1″-H, anomeric proton), 6.33–7.58 (m, 7H, Ar-H), 7.48 (s, 2-H, CH), 9.9 (s, 8′-H, NH), 11.8 (s, 1′-H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): 64.9 (s, C-6″), 73.9 (s, C-4″), 75.2 (s, C-2″), 77.2 (s, C-3″), 81.4 (s, C-5″), 104.1 (s, C-8), 106.2 (s, C-1″, anomeric C-atom), 109.5 (s, C-6), 111.5 (s, C-7′), 115.1 (s, C-10), 118.9 (s, C-3), 119.7 (s, C-4′), 120.3 (s, C-6′), 120.6 (s, C-11′), 122.9 (s, C-5′), 130.9 (s, C-5), 135.1 (s, C-12′), 135.8 (s, C-2′), 136.6 (s, C-10′), 143.1 (s, C-9′), 157.1 (s, C-9), 160.2 (s, C-2), 164.5 (s, C-7), 176.1 (s, C-4, C=O); MS (EI, 70 eV): m/z (%) 480(9) $[M]^+$, 317 (100), 163 (41), 161 (15), 91 (34).

Anal. Calcd. for $C_{24}H_{21}N_3O_8$ (480): C, 60.12; H, 4.41; N, 8.76. Found: C, 60.10; H, 4.27; N, 8.67.

3-(7-Bromo-3,4,-dihydroimidazo[4,5-b]indol-2-yl)-7-O-β-D-glucopyranosyloxy-4H-chromen-4-one (4e)

Yield 81%; $[\alpha]_D^{25} = -14.5$ (c 0.1, DMSO); IR (KBr): 3411(br, OH peak of carbohydrate residue), 2944 (NH), 2855 (glucosidic CH), 2365 (Ar-CH), 1593 (C=O), 1415 (C=N), 1099 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): δ 3.45–4.78 (m, 6H, β-D-glucopyranosyl ring), 5.54 (d, 1″-H, anomeric proton), 6.37–7.79 (m, 6H, Ar-H), 7.54 (s, 2-H, CH), 10.6 (s, 8′-H, NH), 11.5 (s, 1′-H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): 64.6 (s, C-6″), 73.1 (s, C-4″), 74.7 (s, C-2″), 78.1 (s, C-3″), 81.1 (s, C-5″), 103.5 (s, C-8), 106.1 (s, C-1″, anomeric C-atom), 110.1 (s, C-6), 113.0 (s, C-7′), 115.3 (s, C-10), 117.4 (s, C-5′), 118.1 (s, C-3), 120.7 (s, C-4′), 121.0 (s, C-6′), 121.8 (s, C-11′), 131.4 (s, C-5), 134.0 (s, C-12′), 135.6 (s, C-2′), 136.8 (s, C-10′), 142.0 (s, C-9′), 157.4 (s, C-9), 158.8 (s, C-2), 163.8 (s, C-7), 176.1 (s, C-4, C=O).

Anal. Calcd. for $C_{24}H_{20}BrN_3O_8$ (558): C, 51.63; H, 3.61; N, 7.53. Found: C, 51.64; H, 3.60; N, 7.52.

7-O-β-D-Glucopyranosyloxy-3-(7-nitro-3,4,-dihydroimidazo[4,5-b] indol-2-yl)-4H-chromen-4-one (4f)

Yield 75%; $[\alpha]_D^{25} = -18.4$ (*c* 0.1, DMSO); IR (KBr): 3454 (br, OH peak of carbohydrate residue), 2928 (NH), 2852 (glucosidic CH), 2365 (Ar-CH), 1591 (C═O), 1420 (C═N), 1095 (C-O-C); ^{1}H NMR (400 MHz, DMSO-d_6): δ 3.41–4.74 (m, 6H, β-D-glucopyranosyl ring), 5.68 (d, 1″-H, anomeric proton), 6.38–8.52 (m, 6H, Ar-H), 7.59 (s, 2-H, CH), 10.0 (s, 8′-H, NH), 11.3 (s, 1′-H, NH); ^{13}C NMR (100 MHz, DMSO-d_6): 64.1 (s, C-6″), 73.1 (s, C-4″), 75.8 (s, C-2″), 77.2 (s, C-3″), 82.4 (s, C-5″), 104.3 (s, C-8), 106.2 (s, C-1″, anomeric C-atom), 109.9 (s, C-6), 111.8 (s, C-7′), 114.9 (s, C-6′), 115.1 (s, C-10), 116.1 (s, C-4′), 117.8 (s, C-3), 120.8 (s, C-11′), 130.9 (s, C-5), 135.7 (s, C-2′), 136.8 (s, C-10′), 142.2 (s, C-5′), 142.3 (s, C-12′), 142.9 (s, C-9′), 158.2 (s, C-9), 159.0 (s, C-2), 165.1 (s, C-7), 176.1 (s, C-4, C═O).

Anal. Calcd. for $C_{24}H_{20}N_4O_{10}$ (524): C, 54.97; H, 3.84; N, 10.68. Found: C, 54.95; H, 3.80; N, 10.67.

BIOLOGICAL ASSAYS

Antibacterial Assays

The synthesized compounds **4a–f** were screened for their in vitro antibacterial activity against *E. coli*, *K. aerogens*, *S. aureus*, and *B. substilis* by the cup plate diffusion method. The test compounds were dissolved in methanol at a concentration of 100μg/mL by using standard ciprofloxacin and sulphacetamide (100μg/ml) for bacteria. The zone of inhibition after 24 h of incubation at 37°C was compared with standard drugs.

Antifungal Assays

Compounds **4a–f** were also screened at 100μg/ml concentration in methanol against *A. niger* and *C. albicans* for their antifungal activity by the cup plate diffusion method. The zone of inhibition after 7 days at 20°C was compared with standard drugs gentamycin and clotrimazole (100 μg/mL).

Antioxidant Assays

In vitro free radical scavenging activities of **4a–f** were evaluated by DPPH assay method. This method is based on the reduction of a methanolic solution of

the colored DPPH radical. To a set of test tubes containing 3 mL of methanol, 50 μL of DPPH reagent (2 mg/mL) was added. The initial absorbance was measured. To this test tube, methanolic solution of different test solutions (1 mg/mL) were added (10–50 μL). Ascorbic acid (0.5 mg/mL) was added in the range of 10–25μL. After 20 min, absorbance was recorded at 516 nm. The experiment was performed in triplicate. The percentage reduction in absorbance was calculated from the initial and final absorbance of each solution. Percentage scavenging of DPPH radical was calculated using the formula:

$$\% \text{ Scavenging of DPPH} = [(\text{Control} - \text{Test})/\text{Control}] \times 100$$

ACKNOWLEDGMENTS

The authors are sincerely thankful to the Director, SAIF, Chandigarh, and the Head, Department of Chemistry, IIT-Pawai, Mumbai, for providing spectral data of the compounds; Head, Department of Pharmaceutical Sciences, R T M Nagpur University, Nagpur, for biological activity; and Head, Department of Chemistry, R T M Nagpur University, Nagpur, for providing necessary laboratory facilities.

REFERENCES

[1] Wade, L.G. *Organic Chemistry: Fused Heterocyclic Compounds*, 5th Ed.; Pearson Education (Singapore) Pte. Ltd: Delhi, 2004; 706.

[2] Preston, P.N. *Benzimidazoles and Congeneric Tricyclic Compounds*; Interscience-Wiley: New York 1980; Vol. Part 2, 531.

[3] Grimmett, M.R. *Comprehensive Heterocyclic Chemistry*; Pregamon Press: Oxford 1984; Vol. 5, 457.

[4] Weissberger, A. *The Chemistry of Heterocyclic Compounds*; Wiley-Interscience: New York, Part I, 247.

[5] Preston, P.N. Synthesis, reactions, and spectroscopic properties of benzimidazoles. Chem. Rev. **1974**, *74*, 3.

[6] Bradon, D.L.; Binder, R.G.; Betes, A.H.; Montague, C. Monoclonal antibody for multiresidue ELISA of benzimidazole anthelmintics in Liver. J. Agric. Food Chem. **1994**, *42*, 1588–1594.

[7] Dahlen, K.; Wallen, E.A.A.; Grotli, M.; Luthman, K. Synthesis of 2, 3, 6, 8-tetrasubstituted chromones scaffolds. J. Org. Chem. **2006**, *71*, 6863–6871.

[8] Morimoto, M.; Tanimoto, K.; Nakano, S.; Ozaki, T.; Nakano, A.; Komai, K. Insect antifeedant activity of flavones and chromones against spodoptera litura. J. Agric. Food Chem. **2003**, *51*, 389–393.

[9] Varki, A. Biological roles of oligosaccharides: all of the theories are correct. Glycobiology **1993**, *3*, 97–130.

[10] Sears, P.; Wong, C.-H. Enzyme action in glycoprotein synthesis. Cell. Mol. Life Sci. **1998**, *54*, 223–252.

[11] Bertozzi, C.R.; Kiessling, L.L. Chemical glycobiology. Science **2001**, *291*, 2357–2364.

[12] Ryan, C.A. Oligosaccharide signals: from plant defense to parasite offense. Proc. Natl. Acad. Sci. U.S.A. **1994**, *91*, 1–2.

[13] Rudd, P.M.; Elliott, T.; Cresswell, P.; Wilson, I.A.; Dwek, R.A. Glycosylation and the immune system. Science **2001**, *291*, 2370–2376.

[14] Feizi, T. Oligosaccharides that mediate mammalian cell-cell adhesion. Curr. Opin. Struct. Biol. **1993**, *3*, 701–710.

[15] Phillips, M.L.; Nudelman, E.; Gaeta, F.C.A.; Perez, M.; Singhal, A.K.; Hakomori, S.I.; Paulson, J.C. ELAM-1 mediates cell adhesion by recognition of a carbohydrate ligand, sialyl-Lex. Science **1990**, *250*, 1130–1132.

[16] Giannis, A. The sialyl Lewis-X group and its analogs as ligands for selectins: chemo-enzymic syntheses and biological functions. Angew. Chem., Int. Ed. Engl. **1994**, *33*, 178–180.

[17] Yuen, C.-T.; Bezouska, K.; O'Brien, J.; Stoll, M.; Lemoine, R.; Lubineau, A.; Kiso, M.; Hasegawa, A.; Bockovich, N.J.; Nicolaou, K.C.; Feizi, T. Sulfated blood group Lewis. A superior oligosaccharide ligand for human E-selectin. J. Biol. Chem. **1994**, *269*, 1595–1598.

[18] Lacova, M.; Loos, D.; Furdikl, M.; Matulova, M.; El-Shaaer, H.M. Synthesis and reactions of new 4-oxo-4*H*-benzopyran-3-carboxaldehydes containing hydroxy groups or 2-oxopyran cycles. Synth. Molecules **1998**, *3*, 149–158.

[19] Grimmett, M.R. *Imidazole and Benzimidazole Synthesis*; Academic Press: London, 1997, 151

[20] Lewis, P.T.; Wahala, K. Synthesis of the deuterium labeled isoflavone-*O*-glucoside 8, 3′, 5′-D_3-daidzin. Molecules Online **1998**, *2*, 137–139.

[21] Wang, Y.; Li, L.; Wang, Q.; Li, Y. An improved phase transfer catalyzed synthetic method for ononin and rothindin. Synth. Commun. **2001**, *31* (22), 3423–3427.

[22] Lewis, P.; Haltia, S.; Wahala, K. The phase transfer catalysed synthesis of isoflavone-*O*-glucosides. J. Chem. Soc. Perkin Trans. 1 **1998**, *26*, 2481–2484.

[23] Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Vogel's Text Book of Practical Organic Chemistry*, 5th Ed.; Pearson Education (Singapore) Pte. Ltd: Delhi, 2005; Vol. 629-30, 1026–1027.

[24] Ahluwalia, V.K.; Agarwal, R. *Comprehensive Practical Organic Chemistry*: *Preparation and Quantitative Analysis*; University Press: India, 2000, 164.