Journal of Saudi Chemical Society (2014) **18**, 262–268

King Saud University

Journal of Saudi Chemical Society

www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

Synthesis of novel dipodal-benzimidazole, benzoxazole and benzothiazole from cyanuric chloride: Structural, photophysical and antimicrobial studies

Vikas S. Padalkar, Vinod D. Gupta, Kiran R. Phatangare, Vikas S. Patil, Prashant G. Umape, N. Sekar *

Department of Intermediate and Dyestuff Technology, Institute of Chemical Technology (Formerly UDCT), N.P. Marg, Matunga, Mumbai 400 019, Maharashtra, India

Received 17 May 2011; accepted 1 July 2011
Available online 13 July 2011

KEYWORDS

Benzimidazole;
Cyanuric chloride;
Antimicrobial study;
Photo-physics;
Thermal stability;
Triazine

Abstract In the present study, new benzimidazole, benzoxazole and benzothiazole derivatives were prepared and screened for antimicrobial activity. The structure of 4,4′-((6-(4-(diethylamino)phenyl)-1,3,5-triazine-2,4-diyl)bis(oxy))dibenzaldehyde (DIPOD) **5** was established from *p*-hydroxy benzaldehyde **4** and 4-(4,6-dichloro-1,3,5-triazin-2-yl)-*N*,*N*-diethylaniline **3**. The reaction of DIPOD **5** with different *o*-phenylenediamine or *o*-amino phenol or *o*-amino thiophenol in ethanol gave benzimidazole, benzoxazole and benzothiazole **7**. Novel heterocycles showed excellent broad-spectrum antimicrobial activity against bacterial strain (*Escherichia coli*, *Staphylococcus aureus*) and fungal strain (*Candida albicans*, *Aspergillus niger*) cultures. Activity data was compared with standard Streptomycin and Fluconazole drug. Photophysical and thermal properties of synthesized compounds were also studied.

* Corresponding author. Tel.: +91 22 3361 1111/2707, fax: +91 22 3361 1020.
E-mail addresses: n.sekar@ictmumbai.edu.in, nethi.sekar@gmail.com, vikaspadalkar@gmail.com (N. Sekar).

Peer review under responsibility of King Saud University.
doi:10.1016/j.jscs.2011.07.001

Production and hosting by Elsevier

1. Introduction

s-Triazine derivatives represent an important class of compounds due to their potential to be biologically active. They are known to be anti-protozoals (Balini et al., 2005), anticancer agents (Menicagli et al., 2004), estrogen receptor modulators (Henke et al., 2002), antimalarials (Jensen et al., 2001; Agarwal et al., 2005), cyclin-dependent kinase modulators (Kuo et al., 2005), and antimicrobials (Koc et al., 2010. It has been reported that *s*-triazine derivatives are used as templates for molecular imprinting (Tahmassebi and Sasaki, 1994) and for the construction of three-helix bundle protein (Tahmassebi and Sasaki, 1998).

It is also important to note that compounds containing benzimidazole, benzoxazole and benzothiazoles moieties often exhibit diverse biological activities. These heterocycles are known to have antibiotic (Evans et al., 1979), antiviral (Song et al., 2005), anticancer (Kumar et al., 2002), and antimicrobial (Yildiz-Oren et al., 2004) activities. These heterocycles have also been used as ligands for complexes used in asymmetric transformations (Figge et al., 2002). Benzimidazole derivatives are an unique class of broad-spectrum antirhino/enteroviral agents (Nakano et al., 2000), effective against the human cytomegalovirus (HCMV) (Zhu et al., 2000) and efficient selective neuropeptide YY1 receptor antagonists (Zarrinmayeh et al., 1998).

In this paper, we have reported the novel benzimidazole, benzoxazole and benzothiazole derivatives from 4,4′-((6-(4-(diethylamino)phenyl)-1,3,5-triazine-2,4-diyl)bis(oxy))dibenzaldehyde (DIPOD). The DIPOD was prepared by reacting cyanuric chloride with *N*,*N*-diethyl aniline, followed by reaction of 4-(4,6-dichloro-1,3,5-triazin-2-yl)-*N*,*N*-diethylaniline with 2 equivalents of 4-hydroxybenzaldehyde. The compounds are characterized by spectral analysis. Thermal properties and antimicrobial activities of these compounds are studied.

2. Experimental

2.1. Materials and methods

All reagents and solvents were procured from s.d. fine chemicals (India) and were used without purification. The reaction was monitored by TLC using on 0.25 mm E-Merck silica gel 60 F_{254} precoated plates, which were visualized with UV light. The FT-IR spectra were recorded on a Perkin–Elmer 257 spectrometer using KBr disks. ^{1}H-NMR and ^{13}C NMR spectra were recorded on a VXR 400-MHz instrument using TMS as an internal standard. Mass spectra were recorded on a Finnigan Mass spectrometer. The UV–visible absorption spectra of the compounds were recorded on a Spectronic Genesys 2 UV–visible spectrophotometer. Simultaneous DSC-TGA measurements were performed on SDT Q 600 v8.2 Build 100 model of Waters (India) Pvt. Ltd.

2.2. Biological activity

All compounds were evaluated for in vitro antibacterial activities against *Escherichia coli* and *Staphylococcus aureus* strains and in vitro antifungal activity against *Candida albicans* and *Aspergillus niger* strains by using serial dilution method.

2.2.1. General

Incubator at 35 and 37 °C; pipettes of various sizes (Gilson); sterile tips 5, 10, 50, 100, 200 μL sterile normal saline; sterile isosensitest agar (Southern Group Laboratory, SGL); antibiotic solutions (Sigma–Aldrich); sterile solution of 10% (v/v) DMSO in water (Sigma–Aldrich) were used for microbial studies.

2.2.2. Medium

Isosensitest medium was used throughout the assay, as it is pH buffered. Although NCCLS recommends the use of Mueller Hinton medium for susceptibility testing, the isosensitest medium had comparable results for most of the tested bacterial strains (Koeth et al., 2000).

2.2.3. Preparation of the plates

Plates were prepared under aseptic conditions. A sterile 96 well plate was labeled. A volume of 100 μL of test material in 10% (v/v) DMSO (usually a stock concentration of 4 mg/mL) was pipetted into the first row of the plate. To all other wells, 50 μL of nutrient broth was added. Serial dilutions were performed using a multichannel pipette. Tips were discarded after use such that each well had 50 μL of the test material in serially descending concentrations. To each well, 10 μL of resazurin indicator solution was added, using a pipette of 30 μL strength isosensitized, both added to each well to ensure that the final volume was the single strength of the nutrient broth. Finally, 10 μL of bacterial suspension (5×10^6 cfu/mL) was added to each well to achieve a concentration of 5×10^5 cfu/mL. Each plate was wrapped loosely with cling film to ensure that bacteria did not become dehydrated. Each plate had a set of controls: a column with a broad-spectrum antibiotic as positive control, a column with all solutions with the exception of the test compound, and a column with all solutions with the exception of the bacterial solution, adding 10 μL of nutrient broth instead. The plates were prepared in triplicate, and placed in an incubator set at 37 °C for 18–24 h. The color change was then assessed visually. Any color changes from purple to pink or colorless were recorded as positive. The lowest concentration at which color change occurred was taken as the MIC value. The average of three values was calculated and that was the MIC for the test material and bacterial or fungal strain (Sarkar et al., 2007).

2.3. Synthesis of compounds

2.3.1. Synthesis of 4-(4,6-dichloro-1,3,5-triazin-2-yl)-N,N-diethylaniline (3)

A mixture of *N*,*N*-diethylaniline (27 g, 0.2 mol) and cyanuric chloride (18.4 g, 0.1 mol) was heated at 70 °C for 8 h under a slow stream of dry nitrogen, the reaction was monitored by TLC, after completion the reaction mixture was extracted with hot chloroform (200 mL) and the white crystals of hydrochloride salt of *N*,*N*-diethylaniline were removed by filtration. Slow cooling and evaporation of the chloroform extract to a volume of 50 mL yielded good crystals of **3**. The product was recrystallized two times from acetone.

Yield: 11.68 g, 40%; m.p. (Crystallized from acetone) 156 °C.

FT-IR (KBr) υ_{max} cm^{-1}: 824 (C–Cl), 1232 (C–N), 1515 (C═N), 1610 (C═C), 2967 (C–H).

^{1}H NMR (400 MHz, $CDCl_3$, 25 °C) (δ: ppm): 1.23 (t, 6H, –CH_3, J = 6.8, 7.2, 14.0, Hz), 3.46 (q, 4H, –CH_2, J = 6.8, 7.2, 14.0, 14.4 Hz), 6.65–6.69 (dd, 2H, Ar–H, J = 9.2 Hz, 2.8 Hz), 8.29–8.33 (dd, 2H, Ar–H, J = 9.2, 2.8 Hz).

^{13}C NMR (75 MHz, DMSO–d_6, 25 °C) (δ: ppm): 15.6, 49.0, 114.6, 125.6, 130.7, 154.2, 172.3, 179.5.

Mass: m/e = 298 ($M^+ + 1$), 299 ($M^+ + 2$).

2.3.2. 4,4′-((6-(4-(Diethylamino)phenyl)-1,3,5-triazine-2,4-diyl)bis(oxy))dibenzaldehyde (5)

p-Hydroxybenzaldehyde (**4**) (2.426 g, 0.022 mol) and 4-(4, 6-dichloro-1,3,5-triazin-2-yl)-*N*,*N*-diethylaniline (**3**) (3 g, 0.011 mol) were added to a suspension of K_2CO_3 (3.04 g,

0.022 mol) in 50 mL of benzene. The mixture was refluxed for 22 h. The reaction mixture was then cooled and the solid was removed by filtration and washed with hot ethyl acetate twice. The filtrate was extracted with 10% Na_2CO_3 twice and with H_2O once. The organic layer was dried over anhydrous Na_2SO_4 and then concentrated. The white powder was recrystallized from 20 mL of ethyl alcohol to afford 3.31 g of 4,4′-((6-(4-(diethylamino)phenyl)-1,3,5-triazine-2,4-diyl)bis(oxy)) dibenzaldehyde (**5**) as a white fluffy precipitate.

Yield: 3.31 g, 80%; m. p. (Crystallized from ethyl alcohol) 150 °C.

FT-IR (KBr) υ_{max}. cm^{-1}: 1167 (–O– linkage), 1529 (C═N), 1565 (C═C), 1705 (Aldehyde Carbonyl C═O), 2729 (Aldehyde C–H), 2929 (Methyl C–H stretch).

^{1}H NMR (400 MHz, $CDCl_3$, 25 °C) (δ: ppm): 1.19 (t, 6H, –CH_3, J = 6.7, 7.3, 14.3 Hz), 3.42 (q, 4H, -CH_2, J = 6.7, 7.3, 13.9, 14.3 Hz), 6.58 (dd, 2H, J = 9.17, 2.71, Ar–H), 6.61 (dd, 2H, J = 9.17, 2.71, Ar–H), 7.41–7.44 (dd, 4H, J = 8.43, 1.83, Ar- H), 7.97-8.05 (dd, 4H, J = 8.80, 1.83, Ar–H), 10.04 (s, 2H, Aldehyde H).

^{13}C NMR (75 MHz, DMSO-d_6, 25 °C) (δ: ppm):12.3, 43.9, 110.7, 119.2, 122.5, 130.9, 131.1, 133.7, 151.5, 156.2, 171.53, 174.4, 192.9.

Mass: m/e = 469.2 (M^+ + 1).

2.3.3. Synthesis of dipodal benzimidazole, benzoxazole and benzothiazole from DIPOD

The dipodal benzimidazole, benzoxazole and benzothiazole (**7**) were synthesized from DIPOD. To a stirring solution of DIPOD (**5**) (0.5 g, 0.0011 mol) in ethanol, $NaHSO_3$ (0.24 g, 0.0023 mol) in ethanol was added at room temperature. The reaction mixture was treated with *o*-phenylenediamine (0.25 g. 0.0023 mol) or *m*-nitrophenylenediamine (0.365 g, 0.0023 mol) or *m*-chloro-*o*-aminothiophenol (0.34 g, 0.0023 mol) or *o*-aminophenol (0.25 g, 0.0023 mol) in dimethyl formamide (20 mL) and boiled under reflux. After 3 h, the content was poured into ice cold water (20 mL), the precipitate formed was filtered and recrystallized from ethyl alcohol.

2.3.3.1. Data for ***7a***. Yield: 0.67 g, 80%; m.p.: > 168 °C decomposes (Crystallized from ethyl alcohol).

FT-IR (KBr) υ_{max}. cm^{-1}: 1187 (–O– linkage), 1340 (C–N), 1552 (C═N), 2926 (C–H), 3237 (NH).

^{1}H NMR (400 MHz, $CDCl_3$, 25 °C) (δ: ppm): 1.07 (t, 6H, –CH_3, J = 6.7, 7.3, 14.3 Hz), 3.30 (q, 4H, –CH_2, J = 6.7, 7.3, 13.9, 14.3 Hz), 6.21 (d, 2H, NH), 6.47 (dd, 2H, J = 9.2, 8.6 Hz, Ar–H), 6.56 (dd, 2H, J = 9.2, 8.6 Hz, Ar–H), 7.09–7.20 (dd, 4H, J = 2.4, 8.6 Hz, Ar–H), 7.43–7.52 (dd, 4H, J = 9.2, 8.2 Hz, Ar–H), 7.79–7.86 (d, 4H, J = 8.2 Hz, Ar–H), 8.14 -8.29 (d, 4H, J = 8.6 Hz, Ar–H).

^{13}C NMR (75 MHz, DMSO-d_6, 25 °C) (δ: ppm): 12.2, 43.8, 110.1, 119.3, 121.4, 122.9, 128.6, 129.3, 130.5, 131.7, 133.2, 152.4, 154.6, 157.3, 161.3, 170.2, 174.1, 175.0, 175.9.

Mass: m/e = 645.2 (M^+ + 1).

2.3.3.2. Data for ***7b***. Yield: 0.77 g, 76%; m.p.: > 195 °C decomposes (Crystallized from ethyl alcohol).

FT-IR (KBr) υ_{max} cm^{-1}: 1193 (–O– linkage), 1342 (–NO_2), 1352 (C–N), 1559 (C═N), 2925 (C–H), 3235 (NH).

^{1}H NMR (400 MHz, $CDCl_3$, 25 °C) (δ: ppm): 1.08 (t, 6H, –CH_3, J = 6.7, 7.3, 14.3 Hz), 3.31 (q, 4H, –CH_2, J = 6.7, 7.3, 13.9, 14.3 Hz), 6.28 (d, 2H, NH), 6.57 (d, 2H, J = 8.8 Hz, Ar–H), 6.65 (d, 2H, J = 8.8 Hz, Ar–H), 7.13–7.29 (dd, 4H, J = 2.2, 8.4 Hz, Ar–H), 7.46–7.57 (dd, 4H, J = 9.2, 8.5 Hz, Ar–H), 7.84–7.89 (d, 4H, J = 8.5 Hz, Ar–H), 8.16–8.32 (m, 2H, J = 8.8 Hz, Ar–H).

^{13}C NMR (75 MHz, DMSO-d_6, 25 °C) (δ: ppm): 12.3, 43.9, 110.5, 119.3, 121.7, 122.6, 128.3, 130.8, 131.1, 133.7, 152.5, 154.3, 157.1, 161.7, 170.5, 174.7, 175.2, 176.0.

Mass: m/e = 737.5 (M^+ + 1).

2.3.3.3. Data for ***7c***. Yield: 0.85 g, 87%; m.p.: > 200 °C decomposes (Crystallized from ethyl alcohol).

IR (KBr) υ_{max} cm^{-1}: 808 (C–Cl), 1189 (–O–), 1566 (N═N), 1670 (C═C), 2971 (C–H).

^{1}H NMR (400 MHz, $CDCl_3$, 25 °C) (δ: ppm): 1.10 (t, 6H, –CH_3, J = 6.7, 7.3, 14.3 Hz), 3.34 (q, 4H, CH_2, J = 6.7, 7.3, 13.9, 14.3 Hz), 6.36 (d, 2H, Ar–H), 6.67 (d, 2H, J = 8.2, Hz, Ar–H), 6.89 (d, 2H, J = 8.2, Hz, Ar–H), 7.31–7.39 (dd, 4H, J = 2.2, 8.2 Hz, Ar–H), 7.56–7.61 (dd, 4H, J = 9.4, 7.8 Hz, Ar–H), 7.89–7.93 (d, 2H, J = 8.4 Hz, Ar–H), 8.32-8.39 (d, 2H, J = 9.2 Hz, Ar–H).

^{13}C NMR (75 MHz, DMSO-d_6, 25 °C) (δ: ppm): 12.4, 43.8, 110.3, 119.0, 121.4, 122.4, 122.9 128.3, 130.9, 131.4, 133.8, 152.2, 154.0, 157.4, 161.3, 170.3, 174.1, 175.6, 177.2.

Mass: m/e = 716.5 (M^+ + 1).

2.3.3.4. Data for ***7d***. Yield: 0.63 g, 74%; m.p.: > 200 °C decomposes (Crystallized from ethyl alcohol).

FT-IR (KBr) υ_{max}. cm^{-1}: 734 (C–S), 1192 (–O– linkage), 1352 (C–N), 1564 (C═N), 2927 (C–H).

^{1}H NMR (400 MHz, $CDCl_3$, 25 °C) (δ: ppm): 1.08 (t, 6H, –CH_3, J = 6.7, 7.3, 14.3 Hz), 3.34 (q, 4H, –CH_2, J = 6.7, 7.3, 13.9, 14.3 Hz), 6.71 (d, 2H, J = 7.3 Hz), 6.73 (d, 2H, J = 7.3 Hz, Ar–H), 7.10–7.11 (d, 4H, J = 7.3 Hz, Ar–H), 7.27–7.33 (d, 4H, J = 7.3 Hz, Ar–H), 7.47–7.57 (dd, 4H, J = 8.4, 7.7 Hz, Ar–H), 7.96–8.18 (dd, 4H, J = 8.4, 7.7 Hz, Ar–H).

^{13}C NMR (75 MHz, DMSO-d_6, 25 °C) (δ: ppm): 12.4, 43.7, 110.0, 119.3, 121.3, 122.7, 123.9, 128.1, 130.7, 131.3, 133.1, 152.0, 154.3, 157.7, 161.1, 170.0, 174.1, 175.2, 177.1.

Mass: m/e = 679.2 (M^+ + 1).

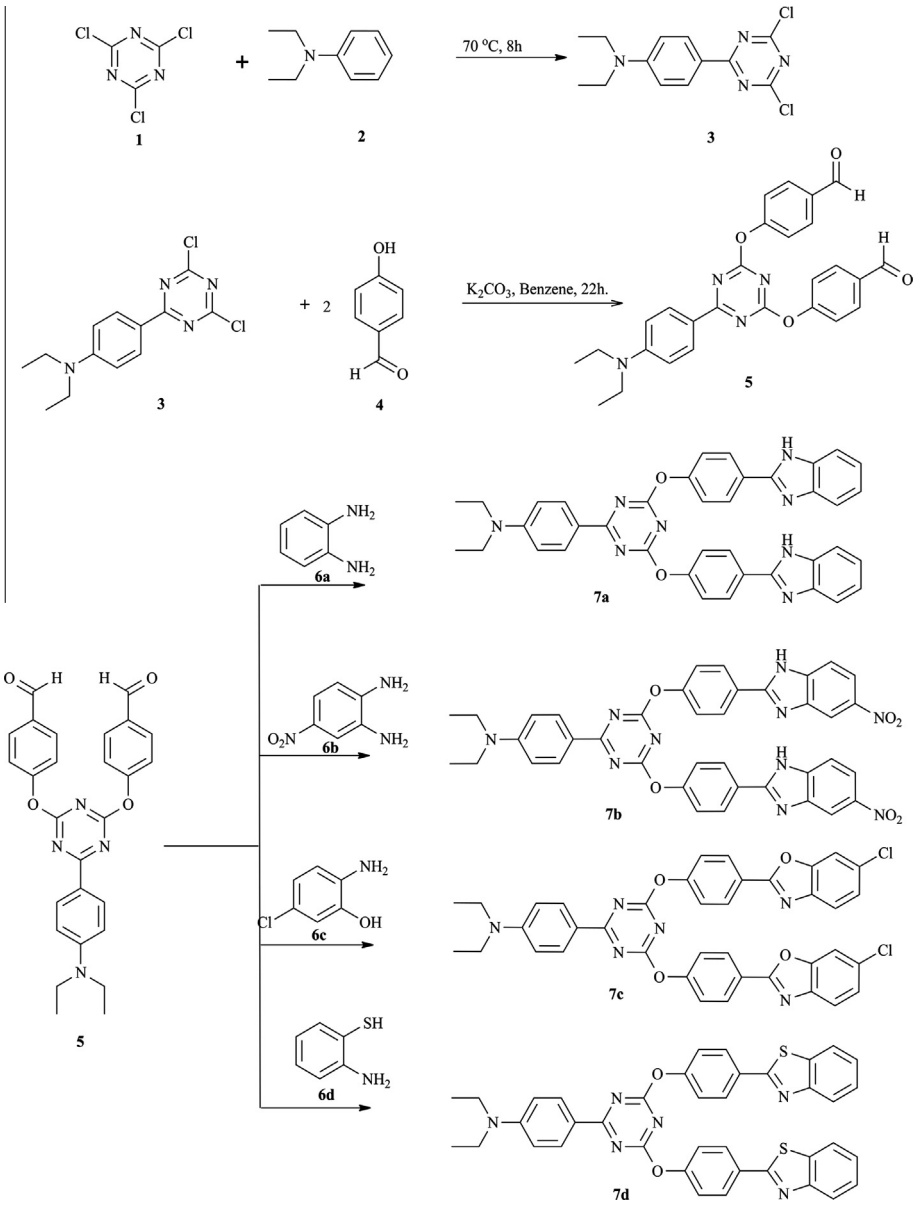
3. Results and discussions

3.1. Chemistry

The synthetic route for DIPOD and its derivatives **7a**–**d** is given in Scheme 1. In ^{1}H NMR spectra of DIPOD, the signal was detected at about 10.04 ppm confirming the formation of DIPOD. Further conversion of DIPOD in dipodal derivatives of benzimidazole, benzoxazole and benzothiazole were confirmed by ^{1}H NMR and ^{13}C NMR. Correlation was observed between donor and acceptor properties of the group attached to the benzimidazole, benzoxazole and benzothiazole nucleus and chemical shift of the proton on each heterocycle.

3.2. Thermal stability

In order to examine the thermal stability of these compounds, thermo gravimetric (TG) analysis was carried out between 40 and 600 °C under nitrogen atmosphere. The TG curves of



Scheme 1 Synthesis of DIPOD derivatives **7a**–**d**.

the compounds were shown in Fig. 1. The TG results showed that the frame work of the synthesized compounds is stable up to 255 °C. Above 255 °C the thermo gravimetric curves of the synthesized compounds showed loss in weight. The comparisons of the T_d (decomposition temperature) showed that the thermal stability of **7a**–**d** decreases in the order **7b** > **7c** > **7a** > **7d**. Thermal stability and their plausible degradation scheme were presented in Fig. 1.

3.3. Photophysical properties

To find out the effect of benzimidazole, benzoxazole and benzothiazole moieties as well as the communication between the electron donating and acceptor termini on photophysical properties of dipodal derivatives, the UV–visible absorption and emission spectra of DIPOD derivatives (**7a**–**d**) were recorded in DMF at room temperature and the compound concentration is 1×10^{-6} M. The λ_{max} (absorbance) values of compounds (**7a**–**d**) were obtained as 376, 383, 393 and 374 nm, respectively Fig. 2 and λ_{max} (emission) values of the compounds **7a**–**d** were obtained as 431, 429, 424 and 419 nm, respectively Fig. 3. It is seen that the absorption-emission characteristics of the compounds **7a**–**d** are nearly same except the fact that the intensities of emission showed some difference; the compound **7c** containing oxazole ring showed a slight red shifted absorption.

Quantum yields of compounds **7a**–**d** were determined by using standard with known quantum yield (Anthracene). Absorption and emission of standard as well as unknown samples were measured at different concentration of unknown samples and standard (2 ppm, 4 ppm, 6 ppm, 8 ppm and 10 ppm). Graphs, absorbance intensity against emission intensity were plotted for standard as well as unknown samples, nature of the graph are straight line; Gradients were calculated

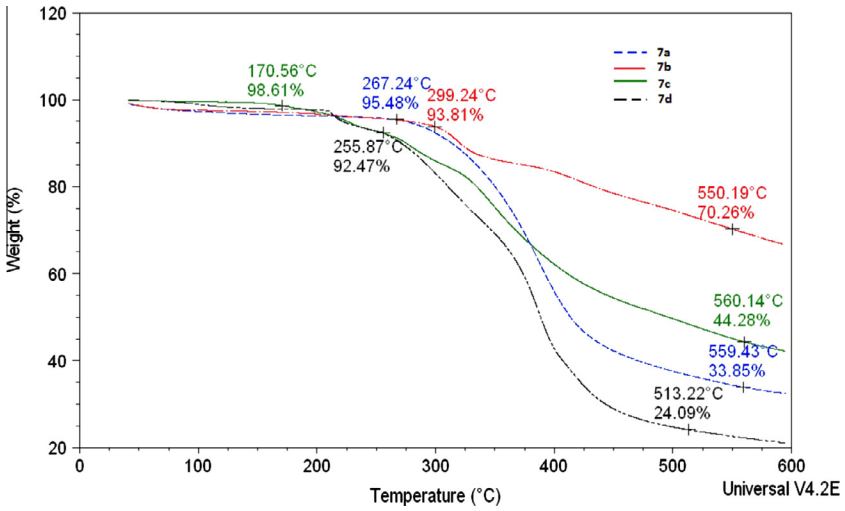


Figure 1 TGA analysis curves of **7a**–**d**.

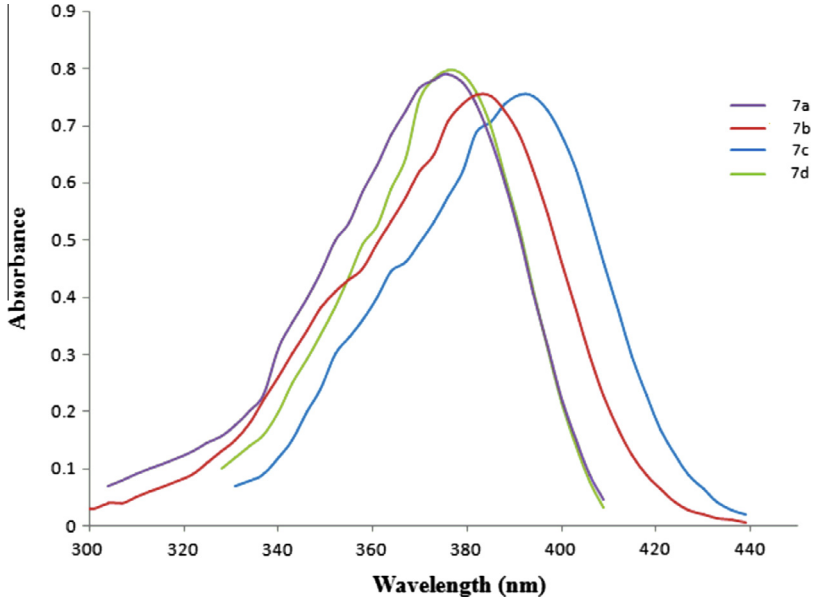


Figure 2 Absorption characteristics of compounds **7a**–**d**.

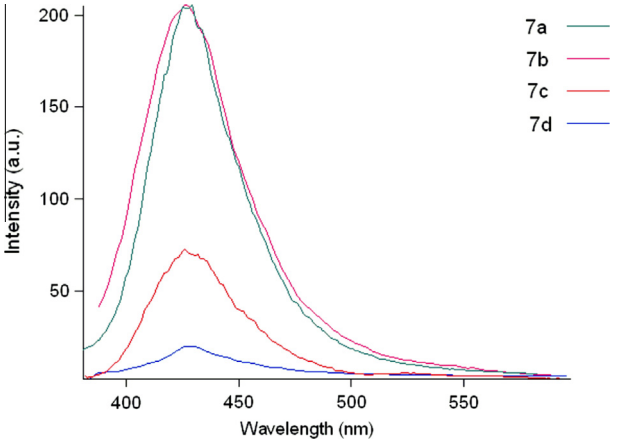


Figure 3 Emission characteristics of compounds **7a**–**d**.

for each compound and for standard. All the measurements were done by keeping the parameters constant such as same solvents and constant slit widths. Relative quantum yield of all synthesized dipod derivatives **7a**–**d** were calculated by using Formula 1 (Williams et al., 1983).

$$\Phi_X = \Phi_{ST}(\mathrm{Grad}_X/\mathrm{Grad}_{ST})(\eta_X^2/\eta_{ST}^2)$$

where Φ_X is the quantum yield of unknown sample, Φ_{ST} the quantum yield of standard used, Grad_X the Gradient of unknown sample, Grad_{ST} the gradient of standard used, η_X^2 the refractive index of solvent for standrad sample, η_{ST}^2 the refractive index of solvent for sample.

The fluorescence quantum yields of **7a**–**d** are recorded in ethanol at room temperature. It is observed that the values of **7b** and **c** in ethanol (0.197 for **7a**, 0.0043 for **7b**, 0.0179 for **7c** and 0.1552 for **7d**) were much lower than those recorded for the **7a** and **d** in the same solvent. Furthermore, as the

Table 1 Absorption, emission and quantum yield of compounds **7a–d**.

Compounds	Absorption λ_{max} (nm)	Emission λ_{max} (nm)	Stokes shift	Quantum yield
7a	376	431	55	0.1970
7b	383	429	46	0.0043
7c	393	424	31	0.0179
7d	374	419	45	0.1552

Table 2 Antimicrobial study of compounds **7a–d**.

Strain	Compounds			
	7a	**7b**	**7c**	**7d**
E. coli	62.5	62.5	62.5	125
S. aureus	250	125	62.5	125
C. albicans	62.5	250	62.5	250
A. niger	125	62.5	62.5	125
Streptomycin	125	125	–	–
Fluconazole	–	–	125	125

Antimicrobial activity was expressed in MIC.
MIC: minimal inhibitory concentration values.
Bacterial strain: *E. coli*; *S. aureus*.
Fungal strain: *C. albicans*; *A. niger*.
Solvent used: DMSO (dimethyl sulfoxide).
Standard: Bacterial strain: Streptomycin 125 μg/mL, Fungal strains: Fluconazole 125 μg/mL.

fluorescence quantum yield of **7a** and **d** was about 10 times higher than that of **7b,** all compounds showed similar fluorescence behavior. The details are given in Table 1.

3.4. Biology

The novel compounds **7a–d** were evaluated for their in vitro antibacterial activity against *E. coli* and *S. aureus* strains and in vitro antifungal activity against *C. albicans* and *A. niger* strains by using the serial dilution method. The minimum inhibitory concentration (MIC) value determined for compounds showed significant growth inhibition zone. The MIC (μg/mL) values recorded in Table 2 indicate that most of the tested compounds displayed variable inhibitory effects on the growth of tested bacterial and fungal strains.

The compounds **7c** showed good antibacterial activity against *E. coli* and *S. aureus* strain and antifungal activity against *C. albicans* and *A. niger* strain. On the other hand, compounds **7a**, **b** and **d** exhibited weak to moderate growth inhibitory as revealed from their MIC values. Among these compounds **7d** showed relatively poor inhibitory activity against both bacterial and fungal strains. Regarding the structure-activity relationship of the novel benzimidazole, benzoxazole and benzothiazole derivative **7a–d** against the tested bacteria, the electron donating and electron withdrawing groups in target molecules **7a–d** affect the growth inhibitory activity against tested bacterial strain. Compound **7c** containing oxazole as electron withdrawing moiety is responsible to enhance the microbial activity.

In general, the tested compounds showed better activity against the bacterial strain (*E. coli*, *S. aureus*) and fungal strain (*C. albicans*, *A. niger*). It would also be noticed that compounds containing oxazole gave better antibacterial and antifungal activity than benzimidazole and benzothiazole compounds. Antibacterial and antifungal activities of newly synthesized compounds were indicated by MIC (μg/mL) value using the modified resazurin assay.

4. Conclusions

Novel benzimidazole, benzoxazole and benzothiazole **7a–d** were synthesized; starting from cyanuric chloride **1** and for their antimicrobial activities were studied. Overall observation from the results of the antimicrobial activities of the synthesized compounds revealed that the compound containing oxazole nucleus is more active than imidazole and thiazole nucleus over tested bacterial and fungal strain. Compounds showed good thermal stability and photophysical properties with improved quantum yield.

References

Agarwal, A., Srivastava, K., Puri, S.K., Chauhan, P.M.S., 2005. Synthesis of 2,4,6-trisubstituted triazines as antimalarial agents. Bioorg. Med. Chem. Lett. 15, 531–533.

Balini, A., Bueno, G.J., Stewart, M.L., Yardley, V., Brun, R., Barrett, P.M., Gilbert, I.H., 2005. Design and synthesis of a series of melamine-based nitroheterocycles with activity against trypanosomatid parasites. J. Med. Chem. 48, 5570–5579.

Evans, D.A., Sacks, C.E., Kleschick, W.A., Taber, T.R., 1979. Polyether antibiotics synthesis, Total synthesis and absolute configuration of the ionophore A-23187. J. Am. Chem. Soc. 101, 6789–6791.

Figge, A., Altenbach, H.J., Brauer, D.J., Tielmann, P., 2002. Synthesis and resolution of 2-(2-diphenylphosphinyl-naphthalen-1-yl)-1-isopropyl-1*H*-benzoimidazole; a new atropisomeric *P*,*N*-chelating ligand for asymmetric catalysis. Tetrahedron: Asymmetry 13, 137–144.

Henke, B.R., Consler, T.G., Go, N., Hale, R.L., Hohman, D.R., Jones, S.A., Lu, A.T., Moore, L.B., Moore, J.T., Orband-Miller, L.A., Robinett, R.G., Shearin, J., Spearing, P.K., Stewart, E.L., Turnbull, P.S., Weaver, S.L., Williams, S.P., Wisely, G.B., Lambert, M.H., 2002. A new series of estrogen receptor modulators that display selectivity for estrogen receptor beta. J. Med. Chem. 45, 5492–5505.

Jensen, N.P., Ager, A.L., Bliss, R.A., Canfield, C.J., Kotecka, B.M., Rieckmann, K., Terpinski, H.J., Jacobus, D.P., 2001. Phenoxypropoxybiguanides, prodrugs of DHFR-inhibiting diaminotriazine antimalarials. J. Med. Chem. 44, 3925–3931.

Koc, Z.E., Bingol, H., Saf, A.O., Torlak, E., Coskum, A., 2010. Synthesis of novel tripodal-benzimidazole from 2,4,6-tris(p-formylphenoxy)-1,3,5-triazine: Structural, electrochemical and antimicrobial studies. J. Hazard. Mater. 183, 251–255.

Koeth, L.M., King, A., Knight May, J., Miller Phillips, I., Poupard, J.A., 2000. Comparison of cation-adjusted Mueller–Hinton broth with Iso-Sensitest broth for the NCCLS broth micro dilution method. J. Antimicrob. Chemother. 46, 369–376.

Kumar, D., Jacob, M.R., Reynolds, M.B., Kerwin, S.M., 2002. Synthesis and evaluation of anticancer benzoxazoles and benzimidazoles related to UK-1. Bioorg. Med. Chem. 10, 3997–4004.

Kuo, G.H., DeAngelis, A., Emanuel, S., Wang, A., Zhang, Y., Connolly, P.J., Chen, X., Gruninger, R.H., Rugg, C., Pesquera, A.F., Middleton, S.A., Jolliffe, L., Murray, W.V., 2005. Synthesis and identification of [1,3,5] triazine-pyridine bi-heteroaryl as a novel series of potent cyclin-dependent kinase inhibitors. J. Med. Chem. 48, 4535–4546.

Menicagli, R., Samaritani, S., Signore, G., Vaglini, F., Via, L.D., 2004. In vitro cytotoxic activities of 2-alkyl-4,6-diheteroalkyl-1,3,5-tria-

zines: new molecules in anticancer research. J. Med. Chem. 47, 4649–4652.

Nakano, H., Inoue, T., Kawasaki, N., Miyataka, H., Matsumoto, H., Taguchi, I., Nagai, T.H., Satoh, T., 2000. Synthesis and biological activities of novel antiallergic agents with 5-lipoxygenase inhibiting action. Bioorg. Med. Chem. 8, 373–380.

Sarkar, S.D., Nahar, L., Kumarasamy, Y., 2007. Microtitre plate-based antibacterial assay incorporating resazurin as an indicator of cell growth, and its application in the in vitro antibacterial screening of phytochemicals. Methods 42, 321–324.

Song, X., Vig, B.S., Lorenzi, P.L., Drach, J.C., Townsend, L.B., Amidon, G.L., 2005. Amino Acid Ester Prodrugs of the Antiviral Agent 2-Bromo-5,6-dichloro-1-(β-d-ribofuranosyl) benzimidazole as Potential Substrates of hPEPT1 Transporter. J. Med. Chem. 48, 1274–1277.

Tahmassebi, D.C., Sasaki, T., 1994. Synthesis of new trialdehyde template for molecular imprinting. J. Org. Chem. 59, 679–681.

Tahmassebi, D.C., Sasaki, T., 1998. Synthesis of three- helix bundle protein by reductive amination. J. Org. Chem. 63, 728–731.

Williams, A.T.R., Winfield, S.A., Miller, J.N., 1983. Relative fluorescence a computer controlled luminescence spectrometer. Analyst 108, 1067–1071.

Yildiz-Oren, I., Yalcin, I., Aki-Sener, E., Ucarturk, N., 2004. Synthesis and structure-activity relationships of new antimicrobial active multi-substituted benzazole derivatives. Eur. J. Med. Chem. 39, 291–298.

Zarrinmayeh, H., Nunes, A.M., Ornstein, P.L., Zimmerman, D.M., Arnold, M.B., Schober, D.A., Gackenheimer, S.L., Bruns, R.F., Hipskind, P.A., Britton, T.C., Cantrell, B.E., Gehlert, D.R., 1998. Synthesis and evaluation of a series of novel 2-[(4-chlorophenoxy)methyl] benzimidazoles as selective neuropeptide Y Y1 receptor antagonists. J. Med. Chem. 41, 2709–2719.

Zhu, Z., Lippa, B., Drach, J.C., Townsend, L.N., 2000. Design, synthesis, and biological evaluation of tricyclic nucleosides (dimensional probes) as analogues of certain antiviral polyhalogenated benzimidazole ribonucleosides. J. Med. Chem. 43, 2430–2437.