"SYNTHESIS, SPECTRAL, AND ANALYTICAL STUDIES OF NEW 6-METHOXY-1, 3-BENZOTHIAZOLES-2-AMINE DERIVATIVES"

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Abstract

New Schiff base derivatives of benzothiazole **2(a-d)** were synthesized through the reaction of 6-methoxy-1,3-benzothiazol-2-amine **1** with various substituted salicylaldehyde (**a-d)**. Determination of compound structures was achieved through the analysis of infrared (IR), proton and carbon-13 nuclear magnetic resonance (1H/13C NMR), and ultraviolet (UV) spectral data. All the recently synthesized compounds underwent screening for their in vitro antibacterial effectiveness against *Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa*, and *B. subtilis*. Additionally, they were assessed for their antifungal activity against *Candida albicans*, and *Saccharomyces cerevisiae*. Compounds **2b,** and **2c** demonstrated superior *in vitro* antibacterial and antifungal efficacy compared to the standard drugs.

Key-words: Evaluation Benzothiazole; Schiff base; Antibacterial activities

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1. Introduction:

Substituted benzothiazoles exhibit a diverse range of pharmacological activities, showcasing their potential as agents with various therapeutic properties. These include antitumor effects[1], anti-microbial properties[2], anthelmintic activity[3], analgesic potential[4], anti-inflammatory characteristics[5], and anticonvulsive actions[6]. Additionally, Schiff bases of thiazole and benzothiazole have been reported to act as inhibitors of lipoxygenase, impacting inflammation and psoriasis[7]. Lipoxygenase is a key enzyme in the biosynthesis of leukotrienes from arachidonic acid. The azomethine linkage has also been studied for its effective role in various biological reactions[8]. Moreover, substituted N-benzothiazol-2-yl-amides represent a significant class of heterocyclic compounds with diverse biological properties[9,10]. These include ubiquitin ligase inhibition[11], antitumor activity[12], anti-rotavirus effects[13], interactions with the adenosine receptor[14], and modulation of the nuclear hormone receptor[15]. Notably, certain benzothiazoles, particularly those substituted at the 4-position with a methoxy moiety, have demonstrated antibacterial, antifungal, and antitubercular activities[16]. Consequently, there is considerable interest in exploring the synthesis of novel Schiff bases of benzothiazole and amides, which have been previously described in the literature[17-20].

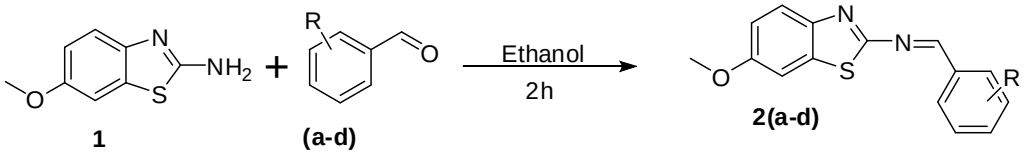
In this current study, we detail the following key aspects: (i) the synthesis of a new Schiff base derived from benzothiazole, and (ii) the comprehensive spectroscopic characterization of the resultant ' compounds. This report provides a thorough exploration of the synthesis process and structural identification of these novel compounds through various spectroscopic techniques.

2. Experimental:

The uncorrected melting points of the compounds were determined using open capillary tubes. Infrared spectra were obtained through KBr pellet IR spectra on a Brucker infrared spectrophotometer. Tetramethyl silane was employed as the internal standard, and 400 MHz BRUKER AVANCE III HD NMR spectrometers were utilized to record ^{1}H-NMR spectra. The FT ^{13}C NMR spectra in $CDCl_3$ were observed at 400 MHz. U.V./Visible spectra spanning the 200-1000 nm range were recorded using a Jasco UV-visible spectrophotometer. This comprehensive range of analytical techniques was employed to characterize and analyze the synthesized compounds thoroughly.

2.1 Synthesis of 6-methoxy-1,3-benzothiazol-2-amine derivatives:

Equal proportions of 6-methoxy-1,3-benzothiazol-2-amine and substituted salicylaldehyde were dissolved in ethanol, forming a reaction mixture. The solution was subsequently refluxed for duration of 2 hours. Following this, the reaction mixture was subjected to cooling in an ice and water solution. The resulting precipitate was meticulously filtered, washed with cold ethanol, and subsequently dried. To enhance the purity, the initial raw material underwent a recrystalisation process using ethanol, as illustrated in **Scheme 1.**



Scheme-1: *Synthesis of Schiff base derivatives of benzothiazole*

Spectral data of synthesized compounds:

4-{[(6-methoxy-1,3-benzothiazol-2-yl)imino]methyl}benzene-1,4-diol (2a):

Yield 86.45%. Anal. Calcd for $C_{15}H_{12}N_2O_3S$: C-59.99%, H- 4.03%, N- 9.33%, O-15.98%, S, 10.68%, Found C- 59.45%, H- 4.00%, N- 9.21%, O-15.91%, S, 10.59%; IR (cm^{-1}): - 3068, 2943 (-OH), 2830 (-CH=), 1636 (C=N), 1583/1492 (C=C), 1457 (Ar C-N), 1328 (C-O), 1252 (C-S), 712, 690 (benzothiazole with aromatic ring), MS 299.05 (M+), ^{1}H NMR (ppm): - 12.07 (*s*, 1H, (-OH, C2), 10.74 (*s*, 1H, Ar-OH C4), 9.24 (*s*, 1H, -CH=), 7.84-7.86 (*dd*, 1H, Ar-H (*J* = 7.98, 0.47)), 7.77-7.80 (*dd*, 1H, Ar-H (*J* = 10.38, 0.44)), 7.69 (*dd*, 1H, Ar-H (*J* = 1.78, 0.44)), 7.16-7.15 (*dd*, 1H, Ar-H (*J* = 7.98, 1.31)), 6.45 (*dd*, 1H, Ar-H (*J* = 1.31, 0.47)), 3.91 (*s*, *3H,* -OCH_3).

4-{[(6-methoxy-1,3-benzothiazol-2-yl)imino]methyl}benzene-1,5-diol (2b):

Yield 74.69%. Anal. Calcd for $C_{15}H_{12}N_2O_3S$: C-59.99%, H- 4.03%, N- 9.33%, O-15.98%, S, 10.68%, Found C- 59.63%, H- 4.03%, N- 9.26%, O-15.89%, S, 10.61%; IR (cm^{-1}): - 3068, 2999 (-OH), 2944 (-CH=), 1637 (C=N), 1583/1492

(C=C), 1457 (Ar C-N), 1330 (C-O), 1288 (C-S), 712, 688 (benzothiazole with aromatic ring), MS 299.12 (M+), ^{1}H NMR (ppm): - 12.07 (*s*, 1H, (-OH, C2), 10.74 (*s*, 1H, Ar-OH C4), 9.23 (*s*, 1H, -CH=), 7.82-7.85 (*ddd*, 1H, Ar-H (*J* = 7.09, 1.48, 0.50)), 7.76-7.78 (*dd*, 1H, Ar-H (*J* = 9.25, 0.45)), 7.68 (*ddd*, 1H, Ar-H (*J* = 7.52, 1.47)), 7.14-7.15 (*ddd*, 1H, Ar-H (*J* = 7.99, 7.36, 1.47)), 6.52-6.54 (*ddd*, 1H, Ar-H (*J* = 7.52, 7.36, 1.47)), 6.45 (*dd*, 1H, Ar-H (*J* = 9.25, 0.45)), 3.89 (*s*, *3H,* -OCH_3).

3,5-dichloro-6-{[(6-methoxy-1,3-benzothiazol-2-yl)imino]methyl}phenol (2c):
Yield 76.89%. Anal. Calcd for $C_{15}H_{10}Cl_2N_2O_2S$: C- 51.00%, H- 2.85%, Cl - 20.07%, N- 9.26%, O- 9.26%, S, 9.06%, Found C- 50.93%, H- 2.81%, Cl -19.98, N- 9.26%, O-15.89%, S, 10.61%; IR (cm^{-1}): - 3127 (-OH), 2948 (-CH=), 1662 (C=N), 1581/1475 (C=C), 1449 (Ar C-N), 1359 (C-O), 1318 (C-S), 765, 682 (benzothiazole with aromatic ring), MS 354.118 (M+), ^{1}H NMR (ppm): - 10.19 (*s*, 1H, Ar-OH), 8.99 (*s*, 1H, -CH=), 7.81-7.83 (*dd*, 1H, Ar-H (*J* = 9.42, 0.44)), 7.67-7.81 (*dd*, 1H, Ar-H (*J* = 8.42, 1.68)), 7.65-7.66 (*dd*, 1H, Ar-H (*J* = 1.70, 0.44)), 7.56-7.58 (*dd*, 1H, Ar-H (*J* = 1.68, 0.48)), 7.12-7.38 (*dd*, 1H, Ar-H (*J* = 9.40, 1.70)), 6.99-7.02 (*dd*, 1H, Ar-H (*J* = 8.42, 0.48)), 3.78 (*s*, 3H*,* -OCH_3).

3,6-dichloro-6-{[(6-methoxy-1,3-benzothiazol-2-yl)imino]methyl}phenol (2d): Yield 78.56%. Anal. Calcd for $C_{15}H_{10}Cl_2N_2O_2S$: C- 51.00%, H- 2.85%, Cl - 20.07%, N- 9.26%, O-15.93%, S, 9.06%, Found C- 50.88%, H- 2.79%, Cl -20.03, N- 9.23%, O-15.89%, S, 9.01%; IR (cm^{-1}): - 3125 (-OH), 2946 (-CH=), 1666 (C=N), 1582/1476 (C=C), 1447 (Ar C-N), 1359 (C-O), 1319 (C-S), 764, 683 (benzothiazole with aromatic ring), MS 354.111 (M+), ^{1}H NMR (ppm): - 10.12 (*s*, 1H, Ar-OH), 9.03 (*s*, 1H, -CH=), 7.82-7.83 (*dd*, 1H, Ar-H (*J* = 9.40, 0.42)), 7.66-7.77 (*dd*, 1H, Ar-H (*J* = 8.40, 1.66)), 7.66-7.65 (*dd*, 1H, Ar-H (*J* = 1.77, 0.43)), 7.54-7.56 (*dd*, 1H, Ar-H (*J* = 1.67, 0.49)), 7.11-7.37 (*dd*, 1H, Ar-H (*J* = 9.41, 1.76)), 6.96-7.03 (*dd*, 1H, Ar-H (*J* = 8.43, 0.49)), 3.78 (*s*, 3H*,* -OCH_3).

2.2Antimicrobial activity:
The effectiveness of the compounds against both Gram-positive bacteria, including *Staphylococcus aureus* (MCC 2408) and *B. subtilis* (MCC 2010), and Gram-negative bacteria, such as *Escherichia coli* (MCC 2412) and *Pseudomonas aeruginosa* (MCC 2080), as well as fungi like *C. albicans* (MCC 1439) and *S. cerevisiae* (MCC 1033), was evaluated using the standard disc-agar diffusion method[21]. Fluconazole was employed as the standard for testing against Gram-negative bacteria, while cephalothin served the same purpose for Gram-positive bacteria, and cycloheximide was used against fungi. Before testing, the compounds were dissolved in dimethylformamide (DMF) at concentrations of 2 and 1 mg/mL, with DMF having no inhibitory effect. The experiments were conducted on a medium consisting of 200 g of potato infusion, 6 g of dextrose, and 15 g of agar, known as potato dextrose agar (PDA). Filter paper disks were impregnated with a 10 mL solution containing a known concentration of test chemicals and carefully positioned on incubated agar surfaces. Mean inhibition zones were determined by measuring the clear zones around each disk after 36 hours of incubation at 27°C for bacteria and 48 hours at 24°C for fungi.

3. Results and discussion:
The synthesis of the title compounds, denoted as **2a-c**, was carried out according to the outlined procedure in **Scheme 1**. The structural characterization of all compounds (**2a–c**) was established through elemental analyses, infrared spectroscopy (IR), proton nuclear magnetic resonance (^{1}H NMR), carbon-13 nuclear magnetic resonance (^{13}C NMR), and mass spectral data. The novel Schiff base **2a-d** was synthesized following the steps detailed in **Scheme 1**. The IR spectra of benzothiazole Schiff bases **2a–d** revealed a characteristic band in the 1636-1666 cm^{-1} range, attributed to (–CH=N–). The organic compounds **2**(**a-d**) that were synthesized displayed a discernible band in the FT-IR spectra, corresponding to the hydroxyl group (-OH) at 3068-3127 cm^{-1} and 2943-2999 cm^{-1}. Additionally, an extra band identified within the wavenumber range of 2830-2948 cm^{-1} has been associated with the presence of the (C=N) functional group. Notably, there were no bands indicative of the (C=O) functional group observed in the FT-IR spectra of compounds **2**(**a-d**). The nuclear magnetic resonance (NMR) spectra of the produced derivatives, namely 6-methoxy-1,3-benzothiazol-2-amine, were obtained. The spectra of compounds **2(a–d)** display a wide peak ranging from 10.12 to 12.07 ppm, as well as another peak ranging from 10.74 to 10.75 ppm. These peaks are associated with the presence of hydroxyl groups (–OH). The ^{1}H NMR spectra of the synthesized compounds did not exhibit signals corresponding to the presence of -NH_2 protons. The ^{1}H nuclear magnetic resonance (NMR) spectra of **2(a-d)** exhibited a proton signal corresponding to the -

CH= group, which appeared in the chemical shift range of 8.99-9.24 ppm.

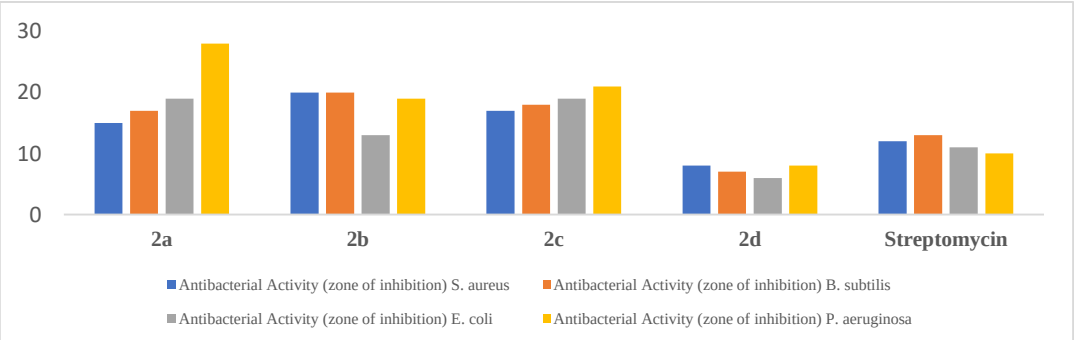
The ^{13}C NMR spectrum exhibited a downfield shift at δ 166.55 ppm due to the presence of the carbon atom double-bonded to nitrogen atoms. Signals for C–4 and C–5 corresponding to the triazole ring were detected at δ 142.95–143.33 and δ 124.67–124.99, respectively. A signal ranging from δ 26.92-27.96 was attributed to the carbon bonded to sulfur, and another signal in the range of δ 52.88-52.90 was attributed to the methylene carbon attached to the nitrogen of the triazole. Electron impact mass spectrometry (EI-MS) of **2a, 2b**, **2c,** and **2d** displayed strong molecular ion peaks (m/z 299.05), (m/z 299.12), (m/z 354.12), and (m/z 354.11), respectively. This supports the conclusion that the reaction of substituted 2-amino-3-methoxybenzothiazole with different substituted salicylaldehyde exclusively produces the Schiff bases, validating the proposed stoichiometry and structure.

Antibacterial Activities:
The in-vitro antibacterial activity of the newly synthesized compounds **2a-d** was assessed against two Gram-positive bacterial strains, namely *Staphylococcus aureus* (MCC-2010) and *Bacillus subtilis* (MCC 2010), as well as two Gram-negative bacterial strains, *Escherichia coli* (MCC-2412) and *Pseudomonas aeruginosa* (MCC 2080), using the conventional disc diffusion method[21]. *Streptomycin* served as the reference standard. The outcomes of the *in-vitro* antibacterial activity screening for the novel series of substituted 6-methoxy-1,3-benzothiazol-2-amines (**2a-d**) are summarized in **Table 1**. Among the compounds tested, three (**2a, 2b**, and **2c**) displayed outstanding antibacterial activity against both Gram-positive and Gram-negative bacteria, while **2d** exhibited moderate to good antibacterial activity against the tested organisms. However, the remaining compounds in the series demonstrated lesser or poor activity against both types of bacteria compared to the standard.

The minimum inhibitory concentration (MIC) was determined as the lowest concentration of a compound inhibiting the growth of the tested microorganisms. Comparing MIC values with the standard ampicillin (MIC = 0.5 µg/mL), compounds **2a, 2b**, and **2d** exhibited the most potent *in-vitro* antibacterial activity against all evaluated organisms. Notably, compounds **2a** (MIC = 25 to 50 µg/mL), **2d** (MIC = 35 to 60 µg/mL), and **2c** (MIC = 30 to 55 µg/mL) demonstrated high antibacterial activity. A brief examination of the structure-activity relationship (SAR) indicated that compounds with a *fluoro* group at positions C-4 of the benzothiazole nucleus contributed to enhanced antibacterial activity. Additionally, the presence of a methoxy (-OCH_3) group on the phenyl ring at either C-3 of the benzothiazole nucleus influenced antibacterial activity. Consequently, compounds **2a, 2b** and **2d** demonstrated excellent in-vitro antibacterial activity against all tested organisms and emerged as active antibacterial agents.

Table 1: Antibacterial studies of **2(a-d)** compounds

Compound	Antibacterial Activity (zone of inhibition)			
	S. aureus	***B. subtilis***	***E. coli***	***P. aeruginosa***
2a	15	17	19	28
2b	20	20	13	19
2c	17	18	19	21
2d	8	7	6	8
Streptomycin	12	13	11	10



4. Antifungal Activities:

The study utilized fluconazole as the reference drug, displaying an MIC of 50 µg/ml against the examined fungal species. Inhibition zones for Candida albicans (MCC1439) and Saccharomyces cerevisiae (MCC1033) ranged from 16 to 25 mm and 19 to 26 mm, respectively. According to Table 2, all tested compounds demonstrated notable fungicidal potential, exhibiting an MIC of 50 µg/ml against both Candida albicans (MCC1439) and Saccharomyces cerevisiae (MCC1033), surpassing the potency of the reference drug.

Table 2: Antifungal studies of **2(a-d)** compounds

Table 2: Antifungal studies of **2(a-d)** compounds

Compound	Antifungal Activity (zone of inhibition)	
	C Albican	*S. Cerevisiae*
2a	7	0
2b	6	0
2c	7	8
2d	8	0
Fluconazole	8	6

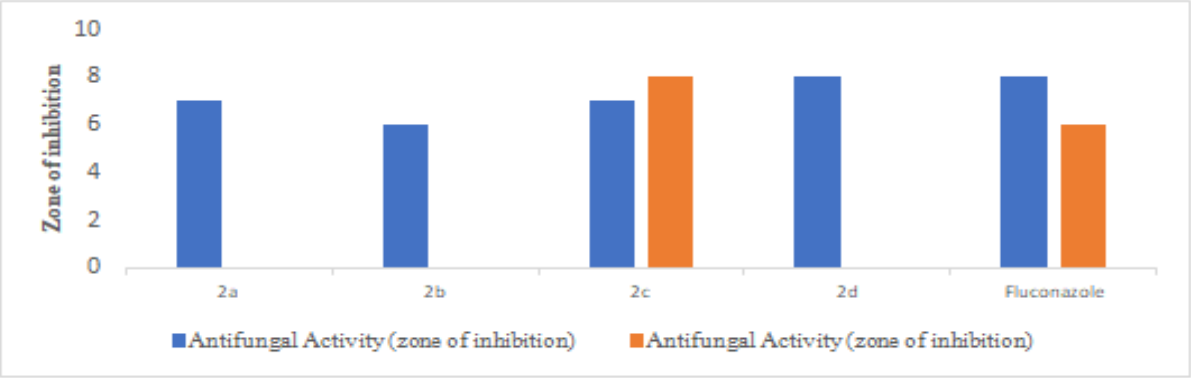
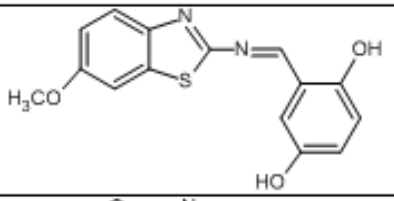
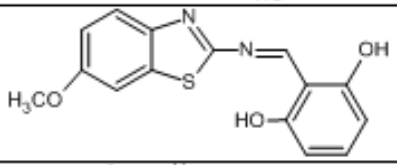
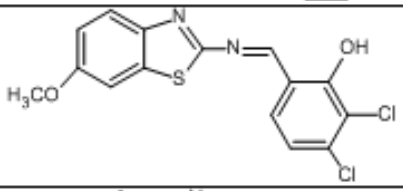
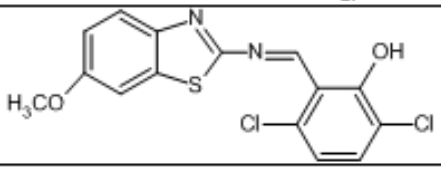


Figure 2: Antifungal activity of compounds **2a-d**

5. Conclusion:

This paper presents the synthesis, spectral analysis, and *in-vitro* antibacterial evaluation of a novel series of 6-methoxy-1,3-benzothiazol-2-amine derivatives, denoted as **2(a-d)**. These heterocyclic compounds were synthesized through a cyclo-dehydration reaction involving various substituted 6-methoxy-1,3-benzothiazol-2-amine derivatives (**2a-d**). The reaction took place in the presence of anhydrous acetonitrile and conc. HCl catalysed. The *in-vitro* antibacterial results are promising, with compounds **2b,** and **2c** exhibiting antibacterial activities comparable to or more potent than the reference drug among the four compounds tested. The MIC values of these compounds indicate that the presence of a *fluoro* group at position C-4 of the benzothiazole nucleus enhances antibacterial potency. Further enhancements in antibacterial activity could potentially be achieved through slight modifications in ring substituents and/or comprehensive additional investigations into structural activity relationships. Based on spectral studies, the structures of complexes are assigned as follows;

Comp Code	MW	Formula	MP	Structure
2a	300.33	$C_{15}H_{12}N_2O_2S$	186	
2b	300.33	$C_{15}H_{12}N_2O_2S$	189	
2c	353.22	$C_{15}H_{10}Cl_2N_2O_2S$	195	
2d	353.22	$C_{15}H_{10}Cl_2N_2O_2S$	197	

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7. Disclosure statement
The authors declare no potential conflict of interest.

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