WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
Coden USA: WJPRAP Impact Factor 8.453
Volume 14, Issue 23, 502-516. Review Article ISSN 2277–7105

ANTIBACTERIAL ACTIVITY OF BENZIMIDAZOLE DERIVATIVES: A MINI REVIEW

***[1]Vaishnavi S. Bawadkar, [2]Dr. Megha T. Salve**

*Shivajirao Pawar College of Pharmacy, Pachegaon, Newasa, Ahilyanagar, Maharashtra, India.

Article Received on 02 Nov. 2025,
Article Revised on 22 Nov. 2025,
Article Published on 01 Dec. 2025,

https://doi.org/10.5281/zenodo.17747790

***Corresponding Author**
Vaishnavi S. Bawadkar
Shivajirao Pawar College of Pharmacy, Pachegaon, Newasa, Ahilyanagar, Maharashtra, India.

How to cite this Article: *1Vaishnavi S. Bawadkar, 2Dr. Megha T. Salve. (2025) ANTIBACTERIAL ACTIVITY OF BENZIMIDAZOLE DERIVATIVES: A MINI REVIEW. "World Journal of Pharmaceutical Research, 14(23), 502–516.

ABSTRACT

Benzimidazole derivatives are widely significant due to their inclusion in various types of medicinal drugs, including anticancer, anticoagulants, antihypertensives, anti-inflammatory, antimicrobials, antiparasites, antivirals, antioxidants, immunomodulators, proton pump inhibitors, hormone modulators, CNS stimulants and depressants, lipid level modulators, antidiabetics, and others. This makes them an essential moiety in medicinal chemistry. Due to this significant importance, it draws the attention of researchers to create more effective benzimidazole derivatives for various biological activity screenings. There are numerous reviews and mini-reviews regarding the significance of the benzimidazole nucleus for medicinal purposes. The present study aims to review the antibacterial activity of compounds containing a benzimidazole nucleus separately, within the period from 2011 to 2017. This review will assist in the creation of effective benzimidazole derivatives.

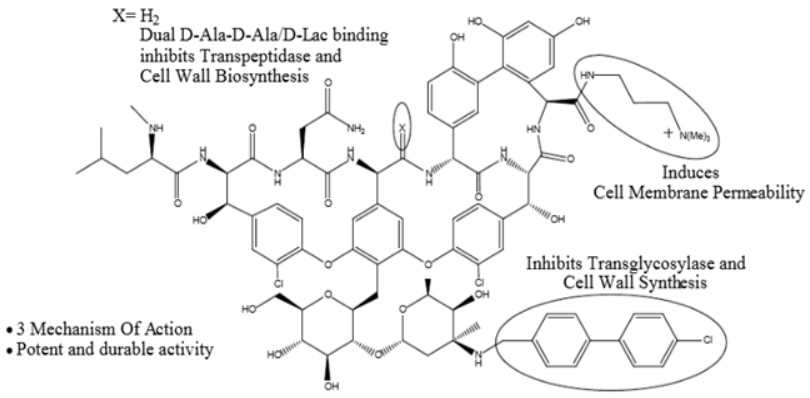
KEYWORDS: Benzimidazole; Medicinal drugs; Antibacterial activity; Synthesis.

INTRODUCTION

Goodman and Nancy Hart published the first paper on the pharmacological properties of benzimidazole in 1943.[1] Their work on benzimidazoles and purins was published by Woolley in 1944. He reported their antibacterial effectiveness against E. coli and Streptococcus lactis[2] as well. Norman GB and Karl Folker isolated a novel basic compound,

5,6-dimethyl benzimidazole, from the acid hydrolysis of Vitamin B-12 in 1949; it was identified as a degradation product.[3] Other degradation products, such as 5,6-methylbenzimidazole and 1,2-diamino-4,5-dimethylbenzene, also demonstrate vitamin B12-like growth activity.[4] Following extensive research, benzimidazole has emerged as a significant heterocyclic system due to the compounds containing its nucleus demonstrating a wide array of + activity against various pathogens and physical disorders. The benzimidazole nucleus is actively involved in various therapeutic agents, including antiparasitics, anticonvulsants, analgesics (Etonitazene), antihistaminics (astemizole), antihelmintics (albendazole, mebendazole, thiabendazole), antiulcers, antihypertensives (candesarten cilexitil, telmisartan), antivirals (enviradine), anticancers, antifungals (Benomyl, Carbendazim), anti-inflammatory agents, proton pump inhibitors (omeprazole, lansoprazole, pantoprazole), and anticoagulants.[5] A number of researchers have synthesized compounds based on benzimidazole and evaluated their antibacterial activity against various bacterial strains. However, no individual compound reaches the clinic. This still represents a failure in benzimidazole chemistry. Infections caused by antibiotic-resistant bacteria pose a major challenge. Many bacteria have developed resistance, rendering a number of antibacterial drugs ineffective. There are numerous well-documented instances of such antibiotic resistance in bacteria (identification year). – Resistenz gegenüber Penicillin Staphylococcus (1940), Tetracycline-Resistenz Shigella, 1959. Staphylococcus mit Methicillinresistenz (1962), Penicillinresistenz Pneumococcus (1965), Erythromycin resistance Streptococcus (1968), Gentamicin-resistenter Enterococcus (1979), Ceftazidime-resistenter Enterobacterlaceae (1987), Vancomycin-resistant Enterococcus (1988), Levofloxacin resistance Pneumococcus (1996), resistance to Imipenem in Enterobacteriaceae (1998), linezolid resistance Tuberkulose (2000), Linezolid-Resistenz bei Staphylococcus (2010), Vancomycin-Resistenz Staphylococcus (2002), Deptomycin resistance Acinetobacter and Pseudomonas (2004/05), resistance to Ceftriaxone Neisseria gonorrhoeae und Enterobacteriaceae (2009), Ceftaroline-Resistenz Staphylococcus (2011).[6] Resistenz gegenüber Vancomycin Staphylococcus (2002), Deptomycin resistance Acinetobacter and Pseudomonas (2004/05), resistance to Ceftriaxone Neisseria gonorrhoeae and Enterobacteriaceae (2009), resistance to Ceftaroline Staphylococcus (2011).[6] Recently, the World Health Organization (WHO) published a brief summary of the global priority list of antibiotic-resistant bacteria. It creates a priority list of these bacteria and categorizes them into three groups: Acinetobacter baumannii (carbapenem-resistant), Pseudomonas aeruginosa (carbapenem-resistant), and Enterobacteriaceae (carbapenem-resistant, 3rd generation

cephalosporin-resistant) are on the critical priority list; Enterococcus faecium (vancomycin-resistant) and Staphylococcus aureus (methicillin-resistant, vancomycin intermediate and resistant) Helicobacter pylori (resistant to clarithromycin), Campylobacter (resistant to fluoroquinolones), Salmonella spp. (resistant to fluoroquinolones) cephalosporin-resistant, □uoroquinolone-resistant) comes under high priority list and Streptococcus pneumonia (penicillin-non-susceptible), Haemophilus in□uenzae (ampicillin-resistant), Shigella spp., (□uoroquinolone-resistant) comes under medium priority list.[7] It is indicated by literature that the excessive use of antibiotics is a clear factor in the evolution of bacterial resistance. In 1945, Alexander Flaming sounded the alarm about the excessive use of antibiotics. The issue of antibiotic resistance has prompted investigations into chemical compounds that may be effective against bacterial infections. Among these, benzimidazole derivatives appear promising, alongside various other organic and inorganic derivatives. Okano et al. conduct research on vancomycin in the pursuit of new antibiotics, modifying its peripheral and binding pocket structures to enhance its durability and potency as an antibiotic.



Compound 18, Summary of activity and Mechanism of action

Chemistry

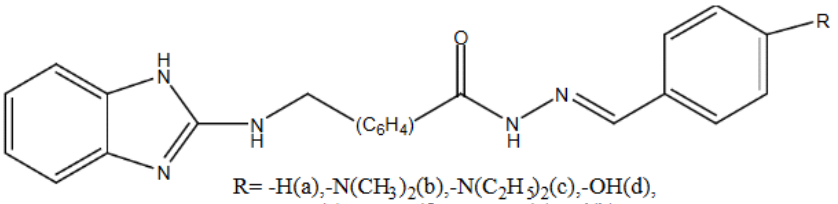
Benzimidazole is an aromatic heterocyclic compound formed by the fusion of an imidazole ring and a benzene ring. Benzimidazole displays amphoteric properties, allowing it to be protonated in acidic conditions and deprotonated when exposed to a strong base such as LiH. Benzimidazole exhibits tautomerism because of hydrogen attached to N-1 in imidazole ring can be shifted to N-3, and exhibit amine-imine tautomerism.

1*H*-benzo[*d*]imidazole

Hoebrecker synthesized benzimidazole for the first time in 1872, producing 2,5- or 2,6-dimethylbenzimidazole (tautomers) by reducing 2-nitro-4-methylacetanilide using an Sn/HCl reducing agent.[9] In 1875, Ladenburg conducted extensive explorations of benzimidazole synthesis through the condensation of O-amino aniline with carbonyl compounds (aldehydes and ketones), following Hoebrecker's work. and others utilizing.[10] Phillips subsequently investigated the Ladenburg synthesis related to the condensation of O-amino aniline with carboxylic acids (specifically, acetic acid). Therefore, the synthesis reaction that produces benzimidazole from O-amino aniline is referred to as the Ladenburg synthesis, Phillips synthesis, or Ladenburg – Phillips synthesis.

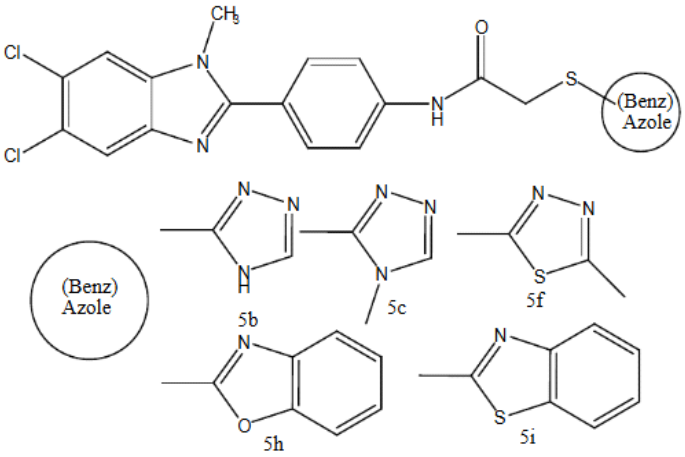
Antibacterial Activity

Özkay et al. conducted a screening of a new series of 14 novel benzimidazole derivatives for antimicrobial activity in 2011. They utilized 9 bacterial strains of the following bacteria: E. coli 35218, E. coli 25922, P. vulgaris, S. thyphimurium, K. pneumoniae, L. monocytogenes, S. aureus, E. faecalis, and B. subtilis. Unfortunately, synthesized compounds of benzimidazole-hydrazones showed no activity against antibacterial effectiveness. Nevertheless, every one of the compounds that were synthesized shows a moderate level of antibacterial action against E. coli.[12] A new series of benzimidazole derivatives containing various (benz)azolylthio moieties were synthesized by the same group of researchers and screened for their antimicrobial activity using bacterial strains such as E. coli 35218, E. coli 25922, P. vulgaris, S. thyphimurium, K. pneumoniae, P. aeruginosa, L. monocytogenes, S. aureus, E. faecalis, and B. subtilis. Compound 5b demonstrates a stronger antibacterial effect against E. coli 35218, with an MIC of 6.25 µg/mL, compared to the reference drug chloramphenicol, which has an MIC of 12.5 µg/mL. Compound 5b, 5c, 5f, 5h, and 5i demonstrate greater antibacterial activity against P. vulgaris. with MIC values of 12.5 (µg/mL), 25 (µg/mL), 25 (µg/mL), 25 (µg/mL), and 12.5 (µg/mL) respectively, which are lower than that of the reference drug chloramphenicol, which has an MIC value of 50 (µg/mL).[13]



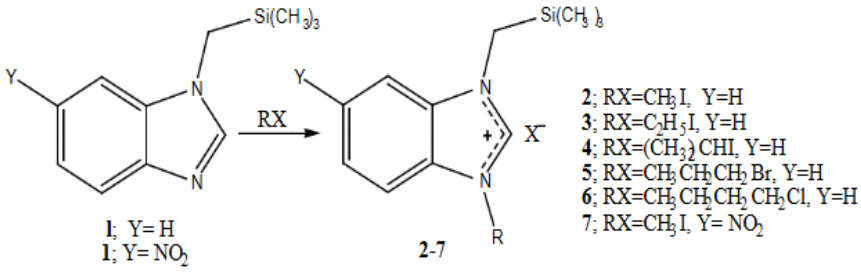
R= -H(a),-N(CH_3)$_2$(b),-N(C_2H_5)$_2$(c),-OH(d), -CH_3(e),-OCH_3(f), -OC_2H_5(g),-Cl(h), -Br(i),-F(j),-NO_2(k),-CF_3(l),-CN(m),-COOH(n)

4-(1H-benzimidazol-2-yl-aminomethyl)-N'-(4-substituted benzylidene) benzohydrazides



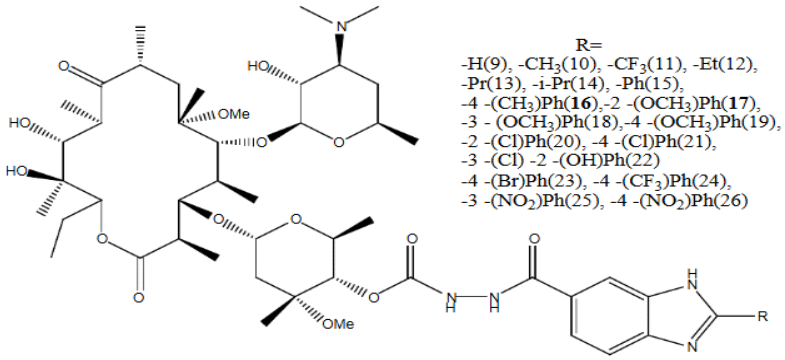
2-[4-[2-[(benz)azolylsulfanyl]acetylamino]phenyl]-5,6-dichloro-1-methyl-1H-benzimidazole

Trimethylsilyl substituted benzimidazole derivatives, which were then tested against standard strains of Gram (-) E. coli and P. aeruginosa bacteria and Gram (+) E. faecalis and S. aureus bacteria. Compound I has the strongest antibacterial action against every bacterial strain, however its MIC value is consistently higher than that of the reference medication ampicillin. With a MIC value of 50 µg/cm3, compounds 2 and 4 show superior antibacterial activity against gram (+) E.faecalis and S. aureus, in addition to compound 1.[14] C. Cong et al. (2011) developed and synthesized a variety of 4"-O-benzimidazolyl clarithromycin derivatives and assessed their antibacterial efficacy against S. aureus ATCC25923, S. pneumoniae ATCC49619, S. pneumoniae B1, S. pneumoniae A22072, S. pneumoniae AB11. When it came to erythromycin-resistant S. pneumoniae that expressed the erm and mef genes, compounds 16 and 17 were the most effective. Furthermore, compound 17 of the 2-methoxypheyl derivative showed the best action against S. aureus ATCC25923 and S. pneumoniae ATCC49619, which are susceptible to erythromycin, with MICs of 0.03 µg/mL and 0.03 µg/mL, respectively. Additionally, it is noteworthy that arylbenzimidazolyl derivatives exhibit greater efficacy than alkyl benzimidazolyl derivatives against strains that are susceptible to and resistant to erythromycin.[15]

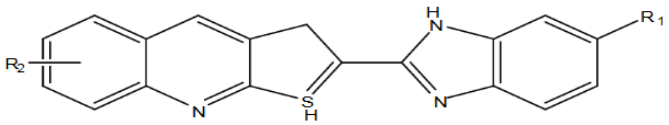


Trimethylsilyl substituted benzimidazole derivatives

Gowda et al. created a new set of 2-(1H-benzimidazol-2-yl)-6-substituted thieno[2,3-b]quinolines and assessed their antibacterial activity against strains of E. coli, S. aureus, P. aeruginosa, and K. pneumonia. Nitro derivatives exhibit antibacterial activity, but it is significantly lower than that of the reference used for comparison. Nitrofurazone.[16]



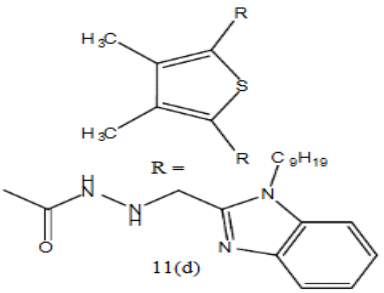
Structure of 4"-O-benzimidazolyl clarithromycin derivatives

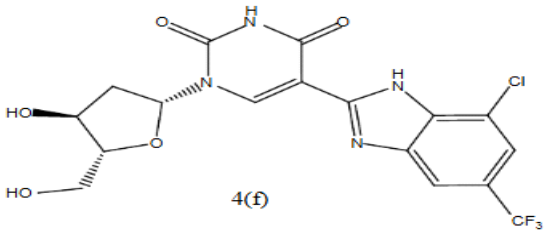


2-(1H-benzimidazol-2-yl)-6-substituted thieno[2,3-b]quinolines

Zhang et al. activity against both gram (+) and gram (−) bacterial strains. Of all the compounds, 11d and its hydrochloride 13b demonstrate remarkable antibacterial activity compared to the reference drugs Norfloxacin, Chloromycin, and Fluconazole. Der MIC-Wert für Verbindung 11d beträgt 2 µg/mL, 2 µg/ mL, 4 µg/mL, 16 µg/mL, 4 µg/mL, 8 µg/mL, 4 µg/mL, 8 µg/mL, and 4 µg/mL against S. aureus, B. subtilis, M. luteus, E. coli, S. dysenteriae, P. aeruginosa, B. proteus and E. typhosa respectively.[17] Krim et al. synthesized a series of novel C-5 benzimidazolyl-20-deoxyuridines with good yields under solvent-free conditions and microwave irradiation, starting from 5-formyl-20-deoxyuridine. The in vitro antibacterial activity of all synthesized compounds (4a–h) was assessed against the following bacterial

strains: S. aureus (ATCC 13709 in vivo, ATCC 25923, oxford and MRSA in vivo), E. faecalis (ATCC 29212 VanS), E. faecium (Van A), S. pneumoniae (Van A, ATCC49619, Pen R and Blood effect), H. influenzae (ATCC 31517 MMSA), E. coli (ATCC 25922) and P. aeruginosa (ATCC 27853). Among all the compounds, 4e and 4f demonstrate notable antibacterial activity, with 4f showing efficacy against gram (+) bacteria such as S. aureus (ATCC 13709 in vivo, ATCC 25923, oxford and MRSA in vivo) at concentrations of 2 µg/ml, E. faecalis at 2 µg/ml, E. faecium at 1 µg/ml, and S. pneumoniae at 4–16 µg/ml. Its potency exceeds that of the two reference drugs except when serum is present, but in the In a second test of this compound, the activity could not be accurately reproduced.[18]





Symmetric bis benzimidazole (sBBZ) conjugates were assessed for antibacterial activity against various gram (+) and gram (-) bacterial strains by Moreira et al. They discovered that para-substituted ethoxy (4), amino (5), and methoxy (9) derivatives exhibited strong bacteriostatic effects against MARS, vancomycin-resistant enterococci, streptococci, and Listeria monocytogenes.[19]

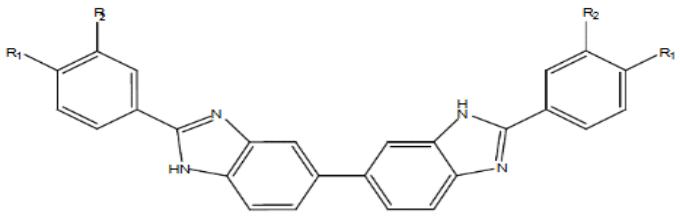
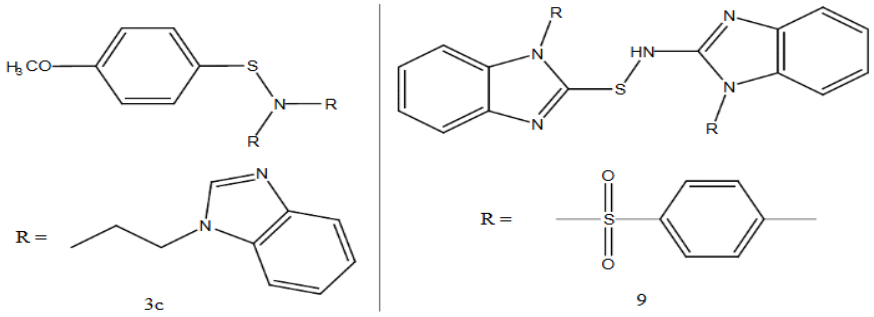


Figure: Structure Of Symmetric Bis Benzimidazole

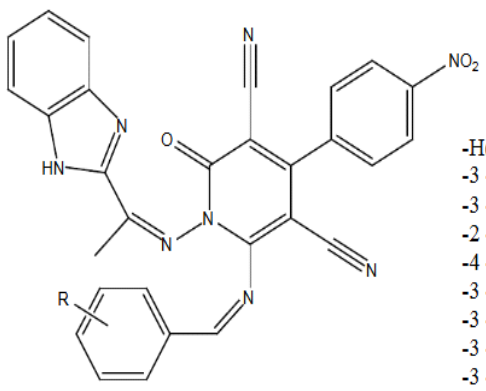
sBBZ	1	2	3	4	5	6	7	8	9	10
R_1	Me	Et	CF_3	OEt	NH_2	Cl	F	H	OMe	OBn
R_2	H	H	H	H	H	H	H	OMe	H	H

Benzimidazole and imidazole derivatives were synthesized by Al-Mohammed et al. All compounds were assessed for antibacterial activity against standard gram (+) strains S. pyogenes, S. aureus, B. subtilis, R. ruber, E. faecalis, and S. epidermidis, as well as gram (-) strains E. coli, S. typhimurium, P. aeruginosa, and A. calcoacetius. Compound 3c and compound 9 demonstrate the most significant antibacterial activities. The reference drugs used were Amoxicillin and kanamycin. Regarding A. calcoacetius, compound 3c has an MIC value of 0.05 µg/mL that is lower than that of the reference drugs, while compound 9 exhibits a lower MIC of 0.30 µg/mL compared to the reference drug kenamycin, which has an MIC of >0.5 µg/mL.[20]



Structure Of 3c and 9

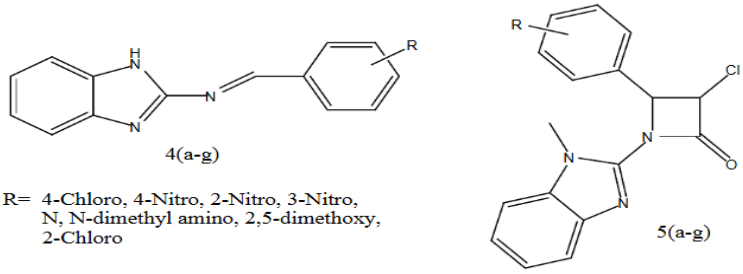
Desai et al. created a set of benzimidazole 2-pyridones and assessed their antibacterial activity in vitro. They utilized two gram (-) bacterial strains, namely E. coli (MTCC-443) and P. aeruginosa (MTCC-1688), as well as two gram (+) bacterial strains, S. aureus (MTCC-96) and S. pyogenes (MTCC-442). The benzimidazole derivatives 5q and 5r show equivalent or even greater antibacterial activity compared to the reference drug. In the case of P. aeruginosa, compound 5q has an MIC value of 12.5 µg/mL, which is higher than that of the reference drugs Ciprofloxacin (50 µg/mL) and Chloramphenicol (50 µg/mL).[21]



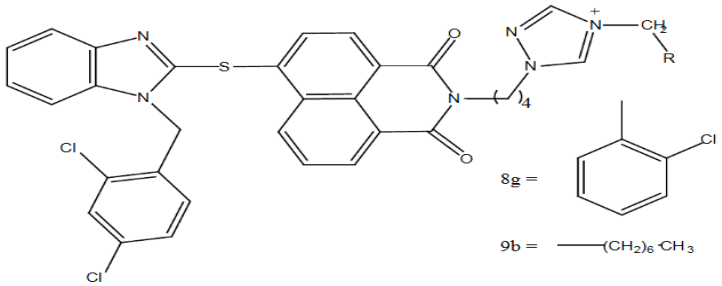
R =
-H(a), -2 -OH(b),
-3 -OH(c), -4 -OH(d),
-3 -F(e), -4 -F(f),
-2 -Cl(g), -3 -Cl(h),
-4 -Cl(i), -2 -CH_3(j),
-3 -CH_3(k), -4 -CH_3(l),
-3 -OCH_3(m), -4 -OCH_3(n),
-3 -NO_2(o), -4 -NO_2(p)
-3 -Br(q), -4 -Br(r)

Structure of benzimidazole derivatives 5(a-r)

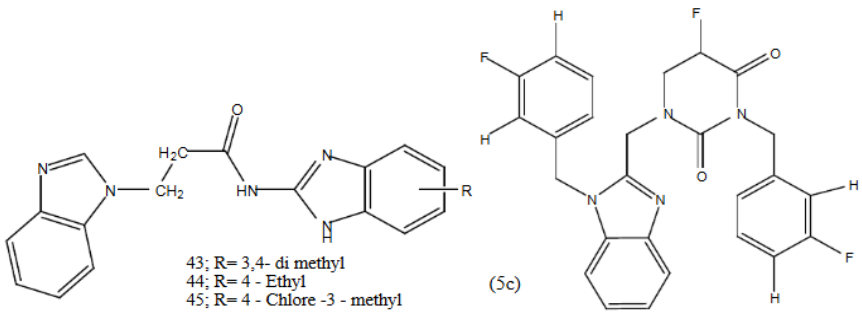
Noolvi et al. synthesized a series of 1-methyl-N-[(substituted-phenylmethylidene)-1H-benzimidazol-2-amines (4a–4g)] and novel azetidine-2-one derivatives of 1H-benzimidazole (5a-5g). They screened all synthesized compounds for antibacterial and cytotoxic activity. The bacterial strains used were S. aureus, B. pumillus, E. coli, and P. aeruginosa. Unfortunately, none of the synthesized compounds exhibited good antibacterial activity compared to the reference drug ampicillin, as measured by MIC values.[22]



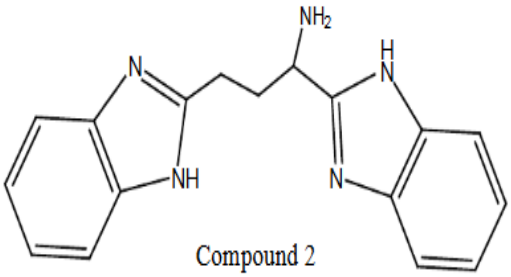
Derivatives of triazole naphthalimide, which are based on benzimidazole, were synthesized by Zhou et al. The antibacterial activity of all the new compounds was screened. Every new compound served as an effective growth inhibitor for the bacterial strain. However, the most effective compounds based on their MIC value are as follows: 8g and 9b (2 ± 0.9 µg/mL) for S. aureus; 8b, 8g and 9b yield values of 14 ± 3.5 µg/mL, 14 ± 3.5 µg/mL, and 29.71 µg/mL respectively for MRSA; 6e (4 ± 0.9 µg/mL), 8b (14 ± 3.5 µg/mL), 8g (4 ± 0.9 µg/mL), 8h (7 ± 1.8 µg/mL), 9b (4 ± 0.9 µg/mL) and 9c (14 ± 7.1 µg/mL) for B. subtilis; 8b (29 ± 7.1 µg/mL), 8g (14 ± 3.5 µg/mL), and 9b (29 ± 7.1 µg/mL) for M. luteus; 6g (4 ± 0.9 µg/mL), 6i (14 ± 3.5 µg/mL), 9b (19 ± 7.1 µg/mL) für B. proteus; 8g (7 ± 1.8 µg/mL) für E. coli; 8b (14 ± 3.5 µg/mL), 8g (14 ± 3.5 µg/mL) für P. aeruginosa; 8g (9 ± 3.5 µg/mL), 9a (19 ± 7.1 µg/mL) für B. typhi. All the values obtained exceed the reference levels of Chloromycine and Norfloxacin. The study indicates that the 8g and 9b derivatives show greater promise for antibacterial activity.[23]



26 neue Benzimidazolderivate, die eine Alkylkette an der N-1-Position von Benzimidazol tragen, wurden von Geeta et al. synthetisiert. Each of the synthesized compounds was tested for antimicrobial activity against the gram (+) bacterial strains S. aureus and B. subtilis, as well as the gram (-) strains E. coli, S. typhi, K. pneumoniae, and P. aeruginosa, in addition to its anti-HIV activity. Compound 37, 43 (with a methyl substitution), 44 (with an ethyl substitution), 45, 50, and 51 demonstrate greater antibacterial activity than the standard,[24] but still lower than that. A series of 5-fluorouracil benzimidazoles was designed and synthesized by Zhou et al. Their findings indicated that each of the synthesized compounds exhibited antibacterial activity ranging from moderate to excellent against all bacterial strains tested. Among all the compounds, 5c shows significant antibacterial activity in comparison to chloromycine and norfloxacin. Compound 5c exhibits MIC values of (2 ± 0.21 µg/mL) against MRSA, (4 ± 0.59 µg/mL) against S. aureus, (16 ± 1.75 µg/mL) against B. subtilis, (64 ± 6.34 µg/mL) against M. luteus, (2 ± 0.21 µg/mL) against E. coli DH52, (8 ± 1.16 µg/mL) against E. coli JM109, (4 ± 0.59 µg/mL) against B. proteus and (8 ± 1.16 µg/mL) against B. typhi.[25]

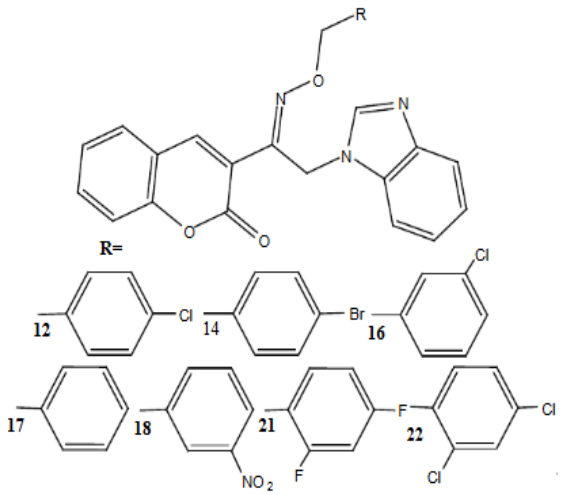


Negi et al. synthesized and evaluated the antibacterial activity of amino acid-derived benzimidazole derivatives against standard bacterial strains, including S. aureus MTCC 1144, S. pneumoniae MTCC 655, S. pyogenes MTCC 442, P. aeruginosa MTCC 2474, and K. pneumoniae MTCC 4030. Compared to other synthesized compounds, Compound 2 (derived from glutamic acid) demonstrates outstanding antibacterial activity against all bacterial strains. In the case of P. aeruginosa, compounds 1 and 2 exhibit greater antibacterial activities than the reference drug erythromycin. Termed the minimum inhibition zone (MIZ)[26], antibacterial activity was demonstrated.



Compound 2

Singh et al. created a new series of 11 novel coumarin-benzimidazole hybrid compounds and evaluated their antibacterial activity against 9 bacterial strains, including gram (+) bacteria (B. subtilis MTCC 1789, B. cereus MTCC 1305, S. aureus ATCC 9144, S. aureus ATCC 6538P, and 4 ATCC 155) and gram (-) bacteria (P. aeruginosa ATCC 25668, P. vulgaris ATCC 29905, K. pneumoniae ATCC 29665, and E. coli MTCC 739). Compound 12 shows considerable activity against B. subtilis, S. aureus ATCC 6538P, P. aeruginosa, and E. coli, with MIC values of 0.95 µg/mL, 1.56 µg/mL, and two instances of 3.12 µg/mL respectively. Compound 14 shows considerable activity against B. subtilis and P. vulgaris, with MIC values of 6.25 µg/mL and 1.56 µg/mL, respectively. Compounds 16, 17, 18, 21, and 22 demonstrate notable activity against P. vulgaris, with MIC values of 12.25 µg/mL, 3.12 µg/mL, 12.25 µg/mL, 1.56 µg/mL, and 1.56 µg/mL respectively.[27]

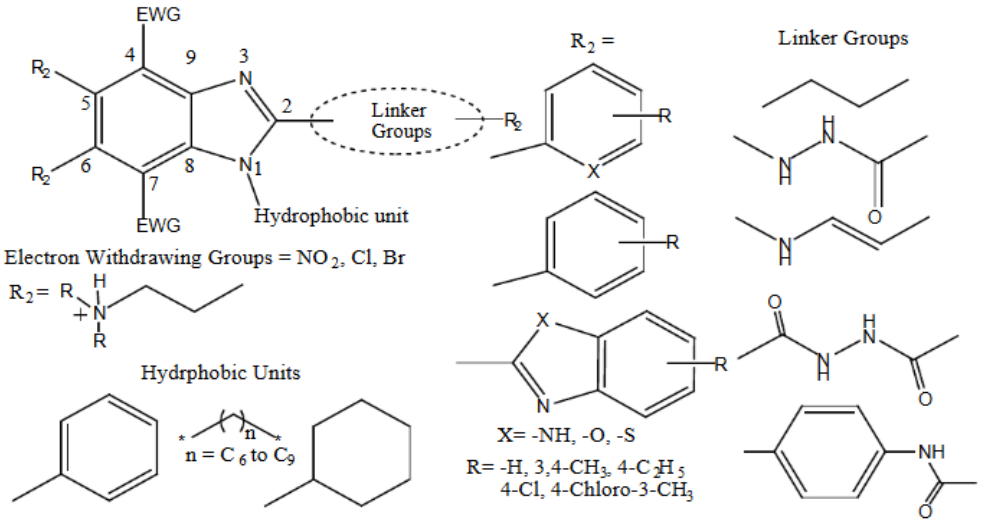


Coumarin-Benzimidazole Hybrid

CONCLUDING DISCUSSION

A number of new compounds featuring a benzimidazole core were created and tested for antibacterial activity as well as other biological activities. Unfortunately, however, no compound has been developed as an antibiotic for clinical use. Based on the discussion

above, it is possible to design a hypothetical model aimed at reducing bacterial infection. The researcher proposes numerous facts regarding structural optimization on the benzimidazole nucleus. For simplification, we present a table (Table 1) of all synthesized compounds along with bacterial strains.



Hypothetical model for bacterial inhibition

We prepare a potential hypothetical model for inhibiting bacterial growth after examining all the facts. As demonstrated in the research by Zhang et al., various substitutions on the benzimidazole nucleus, such as incorporating a hydrophobic unit at N-1 (e.g., benzene, cyclohexane, or an aliphatic chain), are needed to enhance antibacterial activity. The antimicrobial efficiency of compound 11a-f with alkyl chains of varying lengths is superior. At C-2, a benzenoid group is attached via a linker group that contains nitrogen. However, N-3 must remain unsubstituted to avoid potential interactions with lone pair electrons on the nitrogen. Because of the electron density factor, an electron-withdrawing group will be appropriate at C-4 or C-7. It is well-established that the electron density is a crucial factor in achieving the optimal level of activity. Moreover, it is known that a high electron density can impede diffusion through the cell wall of bacteria or microorganisms and may lead to a significant loss of activity. It is necessary for a substituted ammonium group to be located at the C-5 or C-7 position. It raises the permeability of the cell membrane.

Table 1: Effective synthesized compound against bacterial strains.

S. No.	Bacterial strain	Synthesized compound
1	*S. aureus*	Comp I [14]; Comp 17 [15]; Comp 11d, 13b [17]; Comp 4f [18]; Comp 3c, 9 [20]; Comp 8g, 9b [23]; Comp 5c [25]; Comp 12 [27];
2	*K. pneumoniae*	Comp 43, 44, 45 [24]
3	*B. subtilis*	Comp 13b [17]; Comp 3c, 9 [20]; Comp 8g, 9b [23]; Comp 5c [25]; Comp 12 [27]
4	*S. epidermis*	Comp 3c, 9 [20]
5	*P. aeruginosa*	Comp I [14]; Comp 11d, 13b [17]; Comp 5q [21]; Comp 3c, 9 [20]; Comp 8g [23]; Comp 1, 2 [26]; Comp 12 [27]
6	*P. vulgaris*	Comp 5b, 5c, 5f, 5h, 5i [13]; Comp 14, 17, 21, 22 [27]
7	*S. typhimurium*	Comp 3c, 9 [20]
8	*E. coli*	Comp I [14]; Comp 5b [13]; Comp 11d [17]; Comp 3c, 9 [20]; Comp 8g [23]; Comp 43, 44, 45 [24]; Comp 5c [25]; Comp 12 [27]
9	*S. pneumonia*	Comp 17 [15]; Comp 4f [18]
10	*R. ruber*	Comp 3c, 9 [20]
11	*B. proteus*	Comp 13b [17]; Comp 8g, 9b [23]; Comp 5c [25]
12	*B. typhi*	Comp 8g [23]; Comp 5c [25]

REFERENCES

1. Goodman LA, et al. Preliminary investigations on the pharmacology of benzimidazole. Fed Proc., 1943; 2: 1.
2. Woolley DW. Some biological effects produced by benzimidazole and their reversal by purines. J Biol Chem., 1944; 152: 225.
3. Brink NG, et al. J Am Chem Soc., 1949; 71: 2951.
4. Emerson G, et al. J Am Chem Soc., 1950; 72: 3084.
5. Bansal Y and Om S. The therapeutic journey of benzimidazoles: a review. Bioorganic & Medicinal Chemistry, 20: 6208-6236.
6. Ventola CL. The antibiotic resistance crisis: part 1: causes and threats. Pharmacy and Therapeutics, 2015; 40: 277.
7. World Health Organization. Global priority list of antibiotic-resistant bacteria to guide research, discovery, and development of new antibiotics. Geneva: World Health Organization, 2017.
8. Okano, et al. Peripheral modifications of [Ψ [CH2NH] Tpg4] vancomycin with added synergistic mechanisms of action provide durable and potent antibiotics. Proceedings of the National Academy of Sciences, 2017; 04: 125.
9. Hobrecker F. Ber., 1872; 5: 920.
10. Ladenburg A. Ber., 1875; 8: 677.
11. Phillips MA. J Chem Soc., 1928; 172.
12. Özkay O, et al. Antimicrobial activity of a new series of benzimidazole derivatives. Archives of Pharmacal Research, 2011; 34: 1427-1435.

13. Yılmaz Y, et al. Synthesis, microwave-promoted catalytic activity in Suzuki–Miyaura cross-coupling reactions and antimicrobial properties of novel benzimidazole salts bearing trimethylsilyl group. Applied Organometallic Chemistry, 2011; 25: 366-373.
14. Cong T, et al. Synthesis and antibacterial activity of novel 4 -O-benzimidazolyl clarithromycin derivatives. European Journal of Medicinal Chemistry, 2011; 46: 3105-3111.
15. Gowda D, et al. Synthesis, characterization and antibacterial activity of benzimidazole derivatives carrying quinoline moiety, 2011.
16. Zhang, Shao-Lin, et al. "Synthesis and biological evaluation of novel benzimidazole derivatives and their binding behavior with bovine serum albumin." European journal of medicinal chemistry, 2012; 55: 164-175.
17. Krim K, et al. "Efficient microwave-assisted synthesis, antibacterial activity and high fluorescence of 5 benzimidazolyl-2′deoxyuridines." Bioorganic & medicinal chemistry, 2012; 20: 480-486.
18. Moreira M, et al. "Antibacterial activity of head-to-head bis-benzimidazoles." International journal of antimicrobial agents, 2013; 42: 361-366.
19. Al-Mohammed, et al. "Synthesis and antibacterial evaluation of some novel imidazole and benzimidazole sulfonamides." Molecules, 2013; 18: 11978-11995.
20. Desai NC, et al. "Synthesis, antibacterial and antitubercular activities of benzimidazole bearing substituted 2-pyridone motifs." European journal of medicinal chemistry, 2014; 82: 480-489.
21. Noolvi N, et al. "Synthesis, antimicrobial and cytotoxic activity of novel azetidine-2-one derivatives of 1H-benzimidazole." Arabian Journal of Chemistry, 2014; 7: 219-226.
22. Luo L, et al. "Novel benzimidazole derived naphthalimide triazoles: synthesis, antimicrobial activity and interactions with calf thymus DNA." Science China Chemistry, 2015; 58: 483-494.
23. Yadav Y, et al. "Synthesis, Anti-HIV, Antimicrobial Evaluation and Structure Activity Relationship Studies of Some Novel Benzimidazole Derivatives." Anti-Infective Agents, 2017; 13: 65-77.
24. Fang F, et al. "Design, synthesis and biological evaluation of 5-fluorouracil-derived benzimidazoles as novel type of potential antimicrobial agents." Bioorganic & medicinal chemistry letters, 2016; 11: 2584-2588.
25. Negi DS, et al. “Synthesis and in-vitro antibacterial activity of benzimidazole derivatives from some amino acids”. International research journal of chemistry, 2017; 07: 01-15.

26. Singh L, et al. Coumarin-benzimidazole hybrids as a potent antimicrobial agent: synthesis and biological elevation." The Journal of antibiotics, 2017; 1.