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PHARMAKEFTIKI, 37, 2S, 2025 | 407-410 RESEARCH

https://doi.org/10.60988/p.v37i2S.241

Antibacterial activity of phenylboronic acid on pathogenic isolates of *Escherichia coli* and *Staphylococcus aureus*

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KEY WORDS:
phenylboronic acid; *E. coli*; *S. aureus*; agar diffusion; antibacterial

ARTICLE INFO:
Received: December 28, 2024
Revised: n/a
Accepted: January 06, 2025
Available online: October 10, 2025

ABSTRACT

Boron, a bioactive trace element present in humans, plays a critical role in bone formation and maintenance, and exhibits both antibacterial and anti-inflammatory properties. This study investigated the antibacterial activity of boronic acid at varying concentrations in aqueous solution. Phenylboronic acid (PBA) was prepared at concentrations of 3 mg/mL, 6 mg/mL, and 9 mg/mL, and its antibacterial efficacy was assessed using the agar diffusion method against clinically isolated strains of *Escherichia coli* and *Staphylococcus aureus*. The results demonstrated a dose-dependent antibacterial effect of PBA on both bacterial species.

1. Introduction

Arylboronic acids represent a prominent chemical class due to their broad spectrum of applications. Although these compounds have been known for over a century, their properties and uses continue to expand. Key areas of interest include the synthesis of biaryl compounds, molecular receptors, covalent chemical frameworks, and bioactivity profiles[1].

The nature and position of substituents on the phenyl ring significantly influence acidity, receptor binding, and biological activity. Another major area of investigation is optics, with numerous studies exploring the optical properties of boron-containing compounds. Phenylboronic acid (PBA) has garnered attention in drug delivery research. Kitano *et al.* described a glucose-responsive polymer complex incorporating a PBA moiety, which

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Diameter of inhibition zone (mm) by phenyl boronic acid in concentrations (3, 6, 9) mg/mL respectively on *S.aureus and E.coli.*

Bacterial Isolates	Phenyl Boronic Acid Concentration		
	3 mg/mL	6 mg/mL	9 mg/mL
S. aureus	13	14	14
E. coli	15	14	12

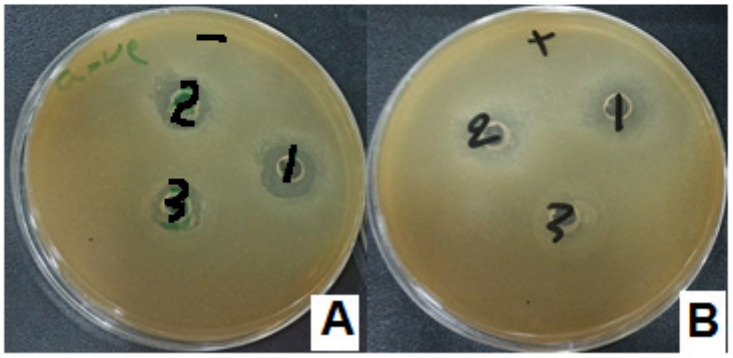

Figure 1. *Agar well diffusion assay to test the antibacterial activity of phenylboronic acid in concentrations 3, 6, and 9 mg/mL, respectively, against E. coli (A) and S. aureus (B).*

functioned as a novel drug delivery system. Recent advances have highlighted the therapeutic potential of boronic acids in antiviral, antibacterial, and anticancer applications[2].

Many antimicrobial agents incorporate halogen atoms, which play a critical and expanding role due to their electronegativity and ability to form complexes with hydrogen bond acceptors. This behaviour has been characterized at the molecular level through electrostatic potential surface analysis. Extensive research has examined the effects of halogenation – specifically chlorination, bromination, and iodination – on antibacterial activity[3]. Halogenation remains a powerful strategy for modulating the properties of bioactive compounds, including antibacterial agents.

Boronic acids are both chemically reactive and stable, with low toxicity. As bioisosteres of carboxylic acids, they share the same periodic group as carbon. Their ability to bind saccharides makes them useful in studying biological systems and identifying metabolites implicated in the aetiology of diabetes. As mild Lewis acids, boronic acids are indispensable in organic synthesis and cross-coupling reactions due to their stability and operational simplicity. They have also been employed as functional groups in anticancer, antiviral, and antibacterial agents. Consequently, halogenated boronic acids have been predicted to exhibit antimicrobial and antibiofilm activity against *Vibrio* species[4].

Boron derivatives have been utilized in the design of novel therapeutic agents, with their biological activity largely dependent on the chemical behavior of the boron atom[5]. Many boron-containing compounds are promising candidates for antimicrobial drug development. A clinically approved cyclic boronic acid derivative has been used to treat urinary tract infections, with its mechanism of action involving inhibition of β-lactamase enzymes; key mediators of bacterial resistance[6].

Accordingly, the aim of this study was to investigate the *in vitro* antibacterial activity of PBA com-

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pounds against *Escherichia coli* and *Staphylococcus aureus*.

2. Methodology

In vitro antibacterial activity was assessed using the agar well diffusion assay. Loopful growths from bacterial isolates were inoculated into nutrient broth and incubated at 37°C for 18 h. The resulting bacterial suspensions were diluted with normal saline, and turbidity was adjusted to match the 0.5 McFarland standard, yielding a uniform suspension containing 1.5×10^8 colony-forming units per milliliter (CFU/mL). A sterile cotton swab was dipped into the adjusted suspension and used in order to streak the entire surface of Mueller–Hinton agar plates for each tested bacterium. Plates were allowed to dry at room temperature for 5–15 min. Using a cork borer, three wells (5-mm diameter) were cut into each plate. Into each well, 20 µL of PBA solution at concentrations of 3, 6, and 9 mg/mL were added. All tests were performed in triplicate. Plates were incubated overnight at 37°C. Following incubation, zones of inhibition were recorded for each concentration and bacterial isolate. The diameters of the inhibition zones were measured in millimeters using a calibrated measuring scale.

3. Results and Discussion

Bacterial antibiotic resistance has emerged as a critical global public health concern. Boron-based organic synthesis has gained prominence due to the unique coordination chemistry of boron, which facilitates the development of novel functionalized compounds. The design and application of boron derivatives have been extensively explored across pharmaceutical domains[7].

In the present study, results illustrated in Figure 1 demonstrate that PBA exhibited antibacterial activity against both *E. coli* and *S. aureus*, as determined by the agar well diffusion assay.

Gram-positive bacteria such as *S. aureus* lack an outer membrane, rendering Gram-negative bacteria more susceptible to PBA complexes than their Gram-positive counterparts[8]. Boronic acid derivatives have also been identified as promising inhibitors of the chromosomal NorA efflux pump in *S. aureus*[9].

The clinical relevance of these compounds is underscored by the approval of five boronic acid or boronic ester-based drugs by the US Food and Drug Administration. Over the past decades, boronic acids have been investigated as inhibitors of penicillin-binding proteins (PBPs), with recent studies focusing on their ability to covalently interact with serine residues. Notably, branched boronic acids have demonstrated inhibitory activity against PBP1b and exhibited measurable antimicrobial effects, including minimum inhibitory concentration values[10].

4. Conclusion

Given the escalating threat of bacterial antibiotic resistance in both Gram-positive and Gram-negative pathogens, the development of novel agents such as PBA represents a promising therapeutic strategy. In this study, PBA demonstrated antibacterial activity against *E. coli* and *S. aureus*, suggesting its potential utility in future antimicrobial therapies. Further research is warranted in order to evaluate the biological activity of PBA against other resistant bacterial strains.

Acknowledgements

The authors express their sincere appreciation to the College of Pharmacy of the University of Babylon, for the financial support of this study.

Conflicts of interest

None exist.

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HOW TO CITE:
Salman H.D., Hammadi A.H., Habeeb S.A., Mahdi Dahadh O.A. Antibacterial activity of phenylboronic acid on pathogenic isolates of *Escherichia coli* and *Staphylococcus aureus*. *Pharmakeftiki* 37(2s), 407-410, 2025. https://doi.org/10.60988/p.v37i2S.241