EVALUATION OF QUATERNARY PHOSPHONIUM SALTS AS POTENTIAL ANTIMICROBIAL AGENTS

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Abstract

The interest in quaternary phosphonium salts increased due to their alignment with the principles of green chemistry, which aim to reduce harm to the environment and human health, while making chemical processes more efficient and sustainable. This study reports the synthesis and applications as antimicrobial agents of five quaternary phosphonium salts.

Introduction

The family of quaternary phosphonium salts explored in this study is particularly appealing due to their unique physicochemical properties, ease of synthesis, and structural versatility. These compounds have broad applicability across multiple fields, including biology, medicine, and industrial processes. The synthesized salts described above were characterized using a combination of one-dimensional and two-dimensional nuclear magnetic resonance (NMR) techniques, which provided detailed information for accurate spectral interpretation. In these compounds, the alkyl chain length, the halide counterions, and the aryl moieties attached to the phosphorus atom were systematically varied. These structural modifications were designed to investigate their influence on the physicochemical properties and potential biological activities of the salts, providing valuable insights into structure–activity relationships and guiding the development of more effective antimicrobial agents [1-3].

Experimental

The quaternary phosphonium salts were evaluated for their antimicrobial activity against two Gram-negative bacterial species (*Escherichia coli* - ATCC 25922 and *Pseudomonas aeruginosa* - ATCC 15692), two Gram-positive bacterial species (*Staphylococcus aureus* - ATCC 25923 and *Bacillus cereus*- ATCC 10878), and one yeast species (*Candida albicans* ATCC 10231). The antimicrobial susceptibility tests were conducted using the disk diffusion method (Kirby-Bauer). Actively growing cultures were used: 24-hour-old cultures for bacteria and 48-hour-old cultures for yeast. Mueller-Hinton broth (Oxoid) was employed for bacterial cultivation, while Sabouraud dextrose agar was used for yeast culture.

Results and discussions

Due to their nucleophilicity, phosphines react with alkyl and aryl halides to form the corresponding phosphonium salts, with reactivity decreasing in the order R'I > R'Br > R'Cl. The general synthetic procedure of quaternary phosphonium salt is following reaction 1.

$$R_3P + R'X \longrightarrow [R_3PR']^+ X^- \quad (1)$$

R = alkyl, aryl, H; R'X = alkyl or benzyl halide.

The structural information was further supported by FTIR spectroscopy and elemental analysis. The findings indicate that by increasing the number of 3-furyl groups attached to the

phosphorus atom leads to shifts to higher fields in the ^{31}P-NMR, which means it shows lover chemical shift (ppm) values [4].

The applicative research on this class of compounds has shown that they are exhibit effect against both Gram-positive (*Bacillus cereus* and *Staphylococcus aureus*) and Gram-negative (*Pseudomonas aeruginosa, Escherichia coli*) strains, and fungus *Candida albicans* [5,6]. To evaluate antimicrobial activity, the diameters of the inhibition zones around each disc were measured using a micrometer, with the total measurement including the 6 mm diameter of the disc itself. The antimicrobial activity of the tested compounds was evaluated in comparison to control sample, which consisted of ethanol solutions (code:1). The most significant antimicrobial activity was observed for samples butyltriphenylphosphonium iodide (4) and pentyltriphenylphosphonium iodide (5), particularly against Gram-positive bacterial strains. As an example, Figure 1 illustrates the results of the antimicrobial testing of these compounds against a culture of *Staphylococcus aureus*. The antibacterial effect observed against *Staphylococcus aureus* was superior to that of the antibiotic used as a positive control (Oxacillin). The preliminary antimicrobial studies conducted on the previously mentioned strains showed promising results, indicating good potential for future applications.

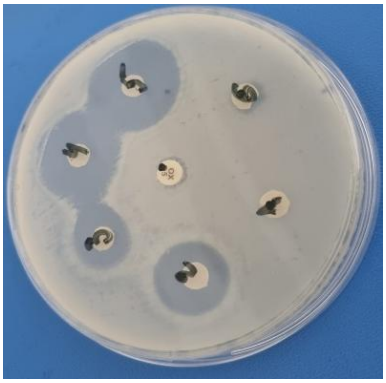

Figure 1. Antibacterial studies on *Staphylococcus aureus.*

Conclusions

This study has demonstrated that these compounds exhibit stronger effects on Gram-positive bacteria (*Bacillus cereus* and *Staphylococcus aureus*), comparing with Gram-negative bacteria (*Pseudomonas aeruginosa* and *Escherichia coli*), and the fungus *Candida albicans*.

References

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