Design, Synthesis and Biological Assessment of Thiazole Derivatives as Possible Antioxidant and Antimicrobial Agents

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Authors’ contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

ABSTRACT

Aims: To synthesize thiazole derivatives and evaluate their therapeutic potential to continue our quest for new antibacterial and antioxidant drugs.

Place and Duration of Study: Institute of Pharmaceutical Research, GLA University, Mathura, Uttar Pradesh, between January 2021 and July 2021.

Methodology: The target compounds in this investigation were synthesized in the search for new molecules having antioxidant and antimicrobial activity. Physicochemical and spectroanalytical studies validated the derivatives molecular structures. Antioxidant and antimicrobial properties of the synthesized molecules were evaluated in vitro using the DPPH and tube dilution methods, respectively.

Results: The majority of the synthesized derivatives displayed antioxidant and antimicrobial activity. The efficacy of the derivatives varied based upon the substituent. Compound 7c exhibited significant antioxidant and antibacterial activity, according to the results of the study.

Conclusion: Our results showed the antioxidant and antibacterial properties of novel thiazole compounds, implying the probability of their utilization in the development of new therapeutics.
Keywords: 2-amino thiazole; synthesis; biological activity, antimicrobial; antioxidant.

1. INTRODUCTION

Over the last few decades, the human population has been affected on an alarming scale across the world by life-threatening infections caused by microorganisms [1]. Bacterial resistance to antibiotics and similar drugs is a real concern in the scientific profession, as many bacterial species have acquired resistance to treatment. The rise in bacterial resistance has not only contributed to an increase in infection-associated mortality and the frequency of infections but has also contributed to the rise in the economic implications of healthcare linked to the treatment of drug-resistant infections [2-4].

Reactive oxygen species (ROS) role in a variety of clinical conditions, including liver and vascular illnesses, inflammatory diseases, rheumatoid arthritis, cancer, and ageing, is well known. An increase in the free radical intake or a reduction in antioxidant concentration are both associated with oxidative stress. The most extreme known DNA change associated with oxidative stress is 8-OH-G, which seems to be a potential marker for carcinogenesis [5]. Antioxidants reduce or prevent oxidative stress-related disorders by neutralizing the damaging effect of ROS.

To address this issue, scientists all around the globe are focusing on novel compounds that can selectively attack new targets in bacteria. As a result, it is critical to investigate novel scaffolds for the development of new antimicrobials to overcome bacterial resistance and establish effective treatments [6]. A critical part of the drug development program to search for new ways is the synthesis of novel compounds that relate to existing molecules via the presence of certain key structural characteristics [7-8].

Heterocyclic compounds play a crucial part, both in pharmaceutical and organic chemistry, owing to their considerable biological activity. Medicinal chemists and researchers continue to focus on heterocycles containing oxygen, nitrogen, and sulfur owing to their diverse pharmacological profiles [9-10]. Thiazole scaffold seems to be a promising candidate for the enrichment of key pharmacophores via the introduction of various functional groups. The first effective antibiotic targeting bacteria had a thiazole ring. Thiazole derivatives are a considerable group of heterocyclic compounds that have therapeutic effects against several diseases [11].

Medicinal and organic chemists have been attracted by the promise of thiazole derivatives as critical precursors for drug discovery and development. Bioactive molecules with a thiazole scaffold have a broad spectrum of activity, including antimicrobial [12-13], antimalarial [14], antitubercular [15], antiviral [16], anti-inflammatory [17], anti-diabetic [18], anthelmintic [19], anticonvulsant [20], antioxidant [21], anticancer [22], and cardiovascular activity [20]. As a result of the above, the present effort was carried out to synthesize thiazole derivatives (Scheme 1) and evaluate their therapeutic potential to continue our quest for new antibacterial and antioxidant drugs.

2. MATERIALS AND METHODS

2.1 Chemicals and Instrumentations

Preliminary material was obtained from approved vendors and used without being purified further. On glass plates coated with silica gel G as the adsorbent, thin layer chromatography was performed, with the mobile phase ethyl acetate/benzene (1:1). The spots were seen using iodine vapors. Using an open capillary apparatus, the melting points were measured and are reported as uncorrected.IR spectra (in KBr) were acquired and expressed in cm\(^{-1}\) using the DRS-8000A accessory method on a Shimadzu IR Affinity-1 FTIR spectrophotometer. Using an appropriate deuterated solvent (CDCl\(_3\)) and tetramethylsilane (TMS) as an internal standard, on a Bruker Avance 500MHz spectrometer, NMR (\(^1\)H and \(^{13}\)C) spectroscopy was accomplished. SAIF, Panjab University, Chandigarh, India, performed spectral analyses, including \(^1\)H and \(^{13}\)C NMR spectroscopy.

Step I:
Step II:

\[
\text{NH}_2 + \text{Cl}_2 \text{O} \xrightarrow{0-5^\circ C, \text{CH}_3\text{COONa}} \text{NH} \text{Cl}_2 \text{O}
\]

Step III:

\[
\text{NH}_2 + \text{Cl}_2 \text{O} \xrightarrow{\text{Reflex, 2h}} \text{NH} \text{Cl}_2 \text{O}
\]

\[R= 4-\text{Cl}-2-\text{NO}_2; 2-\text{Cl}-4-\text{NO}_2; 2-\text{Cl}; 2-\text{NO}_2; 3-\text{Cl}; 3-\text{NO}_2; 4-\text{Br}; 4-\text{Cl}; H\]

Scheme 1. Reaction scheme for target compounds 7a-i

2.2 Reaction Scheme and Synthesis of Thiazole Derivatives

Step 1: Synthesis of 2-amino-4-phenylthiazole (3): [23]

Bromine (0.02mol) was added dropwise with shaking to a solution containing acetophenone (0.01mol) and thiourea (0.2mol). After 24hrs of heating on a water bath, distilled water was added to the reaction mixture. It was heated to the point where the majority of the solid dissipated into the solution. After filtering the heated reaction mixture, the filtrate was cooled. Concentrated ammonium hydroxide was used to make it alkaline. The resulting white precipitate was filtered, washed with water, dried, and recrystallized from ethanol to yield the resultant intermediate. The white precipitate obtained after filtration was dried after being washed with water, followed by recrystallization from ethanol.

Compound 3: Yield: 71%; M.P.: 128-130°C; Rf = 0.72; IR (KBr, cm\(^{-1}\)): 2939(C-H str.), 1597(C=N ring str.), 1492 (C=C ring str.), 781(C-S-C str.), 1294 (C-N str.); 3404 (N-H str.).

Step 2: Synthesis of 2-chloro-N-(substitutedphenyl) acetamide (6a-i): [24]

Aromatic amines (0.05 mol) were dissolved in a mixture of glacial acetic acid (25mL) and a saturated solution of sodium acetate (25mL) and the solution was cooled to 5°C. At 0-5°C, with regular stirring, chloroacetyl chloride (0.07 mol) was added dropwise to this mixture. The impure product was separated by filtration and washed with distilled cold water after being kept at room temperature for 5-6hrs. From aqueous ethanol, the product was recrystallized. Rf values for 6a-i were calculated using a solvent system, ethyl acetate/benzene (1:1). Physicochemical properties of 2-chloro-N-(substitutedphenyl) acetamide are presented in Table 1.

Step 3: Synthesis of 2-(4-phenylthiazol-2-ylamino)-N-substitutedphenyl acetamide (7a-i): [25]

In 15mL 1,4-dioxane, an equimolar quantity (0.05mol) of 2-amino-4-aryl thiazole was combined with various substituted chloroacetanilide derivatives (6a-i). The reaction mixture was then treated with triethylamine (0.005mol) and refluxed for 2hrs. It was cooled and poured over ice. The solid obtained was dried after being filtered and washed with 1% potassium bicarbonate. Physicochemical properties of 2-(4-phenylthiazol-2-ylamino)-N-substitutedphenyl acetamide are presented in Table 2.

7a: 2-(4-phenylthiazol-2-ylamino)-N-(4-chloro-2-nitrophenyl) acetamide:

IR (KBr, cm\(^{-1}\)): 845 (C-CI str.), 861 (C-S str.), 1341 (C-N str.), 1490 (N-O asymmetric stretch), 1602 (C=C str.), 1642 (C=O str.), 3092 (Ar-H str.), 3435 (N-H str. coupled); \(^1\)H NMR (500 MHz, CDCl\(_3\)) \(\delta\) 9.69 (s, 1H, -CONH), 8.30- 7.40 (m,
6H, Ar-H), 6.7 (s, 1H, thiazole ring), 4.46 (s, 2H, CH₂), 1.83 (s, 1H, NH); ¹³C NMR (125 MHz, CDCl₃) δ 167.2, 166, 143.9, 137.1, 135.2, 134.3, 133, 129.9, 129.6, 129.6, 127.5, 127.1, 127, 126.4, 126.2, 110.1, 47.6.

7b: 2-(4-phenylthiazol-2-ylamino)-N-(2-chloro-4-nitrophenyl) acetamide:

IR(KBr, cm⁻¹): 893 (C-Cl str.), 745 (C-S str.), 1327 (C-N str.), 1459 (N-O asymmetric stretch), 1588 (C=C str.), 1696 (C=O str.), 2986 (Ar-H str.), 3376 (N-H str.), 3480 (N-H str. coupled); ¹H NMR (500 MHz, CDCl₃) δ 8.32–7.34 (m, 6H, Ar-H), 7.31 (s, 1H, -CONH), 6.71 (s, 1H, thiazole ring), 4.46 (s, 2H, CH₂), 2.38 (s, 1H, NH); ¹³C NMR (125 MHz, CDCl₃) δ 167.1, 166.1, 144.2, 143.8, 141.4, 134.5, 129.3, 127.5, 127, 125.2, 125, 124.4, 122.3, 110.1, 47.7.

7c: 2-(4-phenylthiazol-2-ylamino)-N-(2-chlorophenyl)acetamide:

IR (KBr, cm⁻¹): 696 (C-Cl str.), 845 (C-Cl str.), 1490 (N-O asymm. str.), 1602 (C=C str.), 1642 (C=O str.), 3092 (Ar-H str.), 3356 (N-H str.), 3435 (N-H str. coupled); ¹H NMR (500 MHz, CDCl₃) δ 7.64–7.03 (m, 9H, Ar-H), 7.13 (s, 1H, -CONH), 6.71 (s, 1H, thiazole ring), 4.40 (s, 2H, CH₂), 2.39 (s, 1H, NH); ¹³C NMR (125 MHz, CDCl₃) δ 167.1, 166.2, 143.8, 135.6, 134.5, 130.6, 129.6, 128.2, 128, 127.6, 127, 126.1, 124.7, 110.4, 47.6.

7d: 2-(4-phenylthiazol-2-ylamino)-N-(2-nitrophenyl)acetamide:

IR(KBr, cm⁻¹): 785 (C-S str.), 1411(C-N str. of Ar-NO₂), 1458 (C=C str.), 1690 (C=O str.), 3018 (Ar-H str.), 3251 (N-H str.), 3410 (N-H str. coupled); ¹H NMR (500 MHz, CDCl₃) δ 7.91 (s, 1H, NH), 8.24–7.34 (m, 9H, Ar-H), 6.70 (s, 1H, thiazole ring), 6.71 (s, 1H, -CONH), 4.41 (s, 2H, CH₂); ¹³C NMR (125 MHz, CDCl₃) δ 167.1, 166.1, 143.7, 136.5, 135.9, 134.5, 133.6, 129.5, 127.5, 127.07, 127, 124.03, 124, 110.4, 47.7.

7e: 2-(4-phenylthiazol-2-ylamino)-N-(3-chlorophenyl)acetamide:

IR(KBr, cm⁻¹): 746 (C-S str.), 822 (C-Cl str.), 1628 (C=O str.), 3066 (Ar-H str.), 3377 (N-H str.), 3498 (N-H str. coupled); ¹H NMR (500 MHz, CDCl₃) δ 7.68–7.11 (m, 9H, Ar-H), 6.70 (s, 1H, thiazole ring), 6.62 (s, 1H, -CONH), 4.35 (s, 2H, CH₂), 4.14 (s, 1H, NH); ¹³C NMR (125 MHz, CDCl₃) δ 167.7, 166.3, 143.8, 139.5, 134.6, 129.9, 129.6, 127.5, 127, 124.8, 120.4, 110.4, 47.6.

7f: 2-(4-phenylthiazol-2-ylamino)-N-(3-nitrophenyl) acetamide:

IR(KBr, cm⁻¹): 711 (C-S str.), 881(C-N str. of Ar-NO2), 1523 (C=C str.), 1681 (C=O str.), 3118 (Ar-H str.), 3377 (N-H str.), 3435 (N-H str. coupled); ¹H NMR (500 MHz, CDCl₃) δ 8.57–7.32 (m, 9H, Ar-H), 6.71 (s, 1H, thiazole ring), 6.49 (s, 1H, -CONH), 4.37 (s, 2H, CH₂), 1.73 (s, 1H, NH); ¹³C NMR (125 MHz, CDCl₃) δ 167.6, 166.3, 148.3, 143.9, 139.3, 134.6, 129.5, 129.2, 127.3, 127, 120.2, 115.8, 110.3, 47.5.

7g: 2-(4-phenylthiazol-2-ylamino)-N-(4-bromophenyl) acetamide:

IR(KBr, cm⁻¹): 498 (C-Br), 773 (C-S str.), 965 (C=C str.), 1610 (C=C str.), 1670 (C=O str.), 3082 (Ar-H str.), 3271 (N-H str.), 3441 (N-H str. coupled); ¹H NMR (500 MHz, CDCl₃) δ 7.63 (dd, J = 7.3, 1.4 Hz, 2H, Ar-H), 7.52 (d, J = 7.5 Hz, 2H, Ar-H), 7.47 – 7.29 (m, 6H, Ar-H), 6.73 (s, 1H, thiazole ring), 6.57 (s, 1H, -CONH), 4.35 (s, 2H, CH₂), 4.18 (s, 1H, NH); ¹³C NMR (125 MHz, CDCl₃) δ 167.7, 166, 143.8, 136.1, 134.2, 131.9, 129.6, 127.6, 129.9, 118.4, 110.4, 47.5.

7h: 2-(4-phenylthiazol-2-ylamino)-N-(4-chlorophenyl) acetamide:

IR(KBr, cm⁻¹): 825 (C-Cl str.), 862 (C-S str.), 1334 (C-N str.), 1598 (C=C str.), 1672 (C=O str.), 3082 (Ar-H str.) 3404 (N-H str. coupled); ¹H NMR (500 MHz, CDCl₃) δ 7.64 (dd, J = 7.4, 1.3 Hz, 2H, Ar-H), 7.48 – 7.29 (m, 7H, Ar-H), 6.71 (s, 1H, thiazole ring), 6.52 (s, 1H, -CONH), 4.33 (s, 2H, CH₂), 4.17 (s, 1H, NH); ¹³C NMR (125 MHz, CDCl₃) δ 167.6, 166.2, 143.9, 136.5, 134.6, 129.5, 129.3, 128.2, 127.6, 127.1, 122.2, 110.1, 47.4.

7i: 2-(4-phenylthiazol-2-ylamino)-N-(4-phenylacetamide:

IR(KBr, cm⁻¹): 690 (C-S str.), 1153 (C-N str.), 1600 (C=C str.), 1649 (C=O str.), 3099 (Ar-H str.), 3404 (N-H str. coupled); ¹H NMR (500 MHz, CDCl₃) δ 7.12-7.75 (m, 10H, Ar-H), 6.70 (s, 1H, thiazole ring), 6.57 (s, 1H, -CONH), 4.35 (s, 2H, CH₂), 4.34 (s, 1H, NH); ¹³C NMR (125 MHz, CDCl₃) δ 167.7, 166, 143.1, 137.8, 134.5, 129.7, 129.3, 127.8, 127.1, 123.7, 121.4, 110.3, 47.6.
Table 1. Physicochemical properties of 2-chloro-N-(substitutedphenyl) acetamides

| Compound | R          | Mol. Formula | Mol. Weight | Color       | Melting Point | Rf Value ** | % Yield |
|----------|------------|--------------|-------------|-------------|---------------|-------------|---------|
| 6a       | 4-Cl-2-NO₂ | C₈H₇ClN₂O₃  | 249         | Orange      | 130-132       | 0.66        | 43.72   |
| 6b       | 2-Cl-4-NO₂ | C₈H₇ClN₂O₃  | 249         | Yellow      | 110-112       | 0.6         | 43.79   |
| 6c       | 2-Cl      | C₈H₇ClNO    | 204         | White       | 126-128       | 0.7         | 31.85   |
| 6d       | 2-NO₂     | C₈H₇ClN₂O₃  | 214         | Creamy White| 116-118       | 0.65        | 10.90   |
| 6e       | 3-Cl      | C₈H₇ClNO    | 204         | White       | 108-110       | 0.68        | 32.68   |
| 6f       | 3-NO₂     | C₈H₇ClN₂O₃  | 214         | Brown       | 120-122       | 0.69        | 47.27   |
| 6g       | 4-Br      | C₈H₇BrClNO  | 248         | Light Brown | 124-126       | 0.66        | 78.11   |
| 6h       | 4-Cl      | C₈H₇ClNO    | 204         | White       | 114-116       | 0.71        | 70.11   |
| 6i       | H         | C₈H₇ClNO    | 169         | White       | 102-104       | 0.7        | 74.35   |

* Melting Point in °C
**Solvent system: Ethyl acetate/benzene (1:1)

Table 2. Physicochemical properties of 2-(4-phenylthiazol-2-ylamino)-N-substitutedphenyl acetamide

| Compound | R          | Color              | Melting Point | Rf Value ** | % Yield |
|----------|------------|--------------------|---------------|-------------|---------|
| 7a       | 4-Cl-2-NO₂ | Light Orange       | 130-132       | 0.6         | 58.63   |
| 7b       | 2-Cl-4-NO₂ | Yellow             | 134-136       | 0.61        | 60.8    |
| 7c       | 2-Cl      | Pale Yellow        | 126-128       | 0.69        | 50      |
| 7d       | 2-NO₂     | Yellow             | 108-110       | 0.7         | 50.80   |
| 7e       | 3-Cl      | Brown              | 152-154       | 0.73        | 38.6    |
| 7f       | 3-NO₂     | Brown              | 104-106       | 0.7         | 68.28   |
| 7g       | 4-Br      | Creamy White       | 156-158       | 0.7         | 86.04   |
| 7h       | 4-Cl      | Cream              | 124-126       | 0.66        | 65      |
| 7i       | H         | Light Brown        | 156-158       | 0.68        | 51      |

* Melting Point in °C
**Solvent system: Ethyl acetate/benzene (1:1)

2.3 Biological Screening of the Synthesized Derivatives

2.3.1 Evaluation of Antioxidant Activity

The Shimada method, which is based on the theory of scavenging the 2,2-diphenyl-2-picrylhydrazyl (DPPH) radical, was used to evaluate the free radical scavenging activities of synthesized compounds in reference to ascorbic acid [26]. In methanol, different concentrations of synthesized derivatives and ascorbic acid (10-100μg/ml) were prepared, and to 1mL of 0.1mM DPPH solution, 1mL of each concentration of test compound and ascorbic acid was added. The absorbance was assessed using UV at 517nm once the mixture was held in a dark place at room temperature for 30 minutes after intense shaking [27].

The following formula was used to calculate the % scavenging of the free radical DPPH:

\[
\text{% scavenging} = \frac{\text{Ac} - \text{At/s}}{\text{Ac}} \times 100 \quad (1)
\]

Where,

\text{Ac} = \text{Absorbance of test compounds/ standard}
\text{At/s} = \text{Absorbance of control}

Each sample's IC\text{50} value was obtained using a graph displaying percent inhibition against different concentrations of synthesized compounds. IC\text{50} value is a test sample concentration that decreases the initial DPPH concentration by 50%. A lower mean concentration value of the inhibitor indicates a stronger free radical scavenging activity.

2.3.2 Evaluation of Antimicrobial Activity

By using the tube dilution technique, derivatives were evaluated for in vitro antimicrobial activity against Bacillus subtilis (MTCC 441), Escherichia coli (MTCC 443), and Candida albicans (MTCC 227). The findings were compared to those obtained with Ampitetrin B (antifungal) and Ciprofloxacin (antibacterial) as references. The stock solutions for the standard and test compounds were produced in DMSO at a concentration of 1024μg/mL. Fresh pure cultures were used to prepare the bacterial and fungal
inoculums. In test tubes containing successive dilutions (512, 256, 128, 64, and 36μg/ml) of test and reference compounds in Nutrient Broth and Potato Dextrose Agar medium, 10μL of adequately diluted inoculum was introduced. It was then incubated for 24hrs (bacteria) and 48hrs (fungi) at 37 ± 1°C. The findings of antimicrobial screening were expressed in terms of the lowest concentration of test chemicals that inhibited the growth of bacteria, referred to as the minimum inhibitory concentration (MIC) [27].

3. RESULTS AND DISCUSSION

3.1 Chemistry

Novel thiazole compounds were synthesized as part of this study (7a-i). Acetophenone, bromine, and thiourea were reacted with ammonium hydroxide as a base to synthesize 2-amino-4-phenyl-thiazole (3). Under cold conditions, chloroacetyl chloride and various aromatic amines were reacted to afford 2-chloro-N-(substitutedphenyl) acetamide (6a-i). By reacting equimolar amounts of various 2-chloro-N-(substitutedphenyl) acetamides and 2-amino-4-phenyl-thiazole in the presence of triethylamine, target compounds were produced in optimal yields. All of the spectroscopic techniques used to characterize the synthesized derivatives corresponded with the designated chemical structures.

3.2 Biological Screening of the Synthesized Derivatives

3.2.1 Antioxidant Activity

Synthesized derivatives were examined for antioxidant potential in vitro using the DPPH method with ascorbic acid as the reference. IC\textsubscript{50} value of synthesized compounds was determined by plotting concentrations against percent inhibition of the test compound. The results revealed that only a few molecules exhibited considerable antioxidant activity. 7f and 7c exhibited exceptional antioxidant capabilities, with IC\textsubscript{50} values and inhibition percentages comparable to ascorbic acid (Fig. 1). Table 3 summarizes the results of the antioxidant screening.

Table 3. Antioxidant properties of synthesized thiazole derivatives

| Compound Code | Concentration | IC\textsubscript{50}** |
|---------------|---------------|------------------------|
|               | 10 | 25 | 50 | 75 | 100 | Standard * |
| 7a            | 6.44 | 10.9 | 16.21 | 38.38 | 56.16 | 95.59 |
| 7b            | 2.76 | 7.22 | 12.53 | 41.78 | 49 | 100.95 |
| 7c            | 35.4 | 43.2 | 56.86 | 69.05 | 84.77 | 34 |
| 7d            | 39.02 | 43.41 | 49.36 | 51.62 | 57.86 | 60.82 |
| 7e            | 24.36 | 40.65 | 47.5 | 52.4 | 76.34 | 55.51 |
| 7f            | 42.49 | 48.79 | 61.89 | 68.27 | 73.01 | 26.37 |
| 7g            | 30.2 | 45.27 | 62.52 | 69.87 | 86.6 | 36.94 |
| 7h            | 37.74 | 46.67 | 54.6 | 62.039 | 65.72 | 41 |
| 7i            | 40.43 | 41.71 | 50 | 62.39 | 76.55 | 41.71 |

**Ascorbic Acid

**µg/ml

![Fig. 1. Antioxidant properties of the synthesized thiazole derivatives in reference to Ascorbic acid](image-url)
Table 4. In vitro antimicrobial activity of synthesized thiazole derivatives

| Compound | **MIC** | **B. subtilis** | **E. coli** | **C. albicans** |
|----------|---------|-----------------|-------------|-----------------|
| Ciprofloxacin | <100    | <100            | -           | -               |
| Amphotericin B  | -       | 128             | 128         | 128             |
| 7a        | 128     | 128             | 128         |                 |
| 7b        | 128     | 128             | 128         |                 |
| 7c        | 64      | 64              | 128         |                 |
| 7d        | 256     | 128             | 64          |                 |
| 7e        | 128     | 128             | 128         |                 |
| 7f        | 128     | 256             | 128         |                 |
| 7g        | 128     | 128             | 128         |                 |
| 7h        | 64      | 64              | 256         |                 |
| 7i        | 256     | 256             | 256         |                 |

*MIC: μg/mL

3.2.2 Antimicrobial Activity

Against *Bacillus subtilis*, *Escherichia coli*, and *Candida albicans*, antimicrobial activity was assessed *in vitro* using the tube dilution technique. Following examination, the findings were represented as MIC. Table 4 summarizes the MIC values for both standard and synthesized compounds. The antimicrobial properties of all produced compounds were seen to be considerable, with distinct compounds active against different microbes. Compounds 7c and 7h were the most potent antibacterial agents, whereas 7d was perhaps the most potent antifungal, according to the findings.

4. CONCLUSION

The synthesis of new thiazole compounds, as well as their pharmacological potential, are discussed in this study. On the benzylidene ring, the electron-withdrawing group imparted the greatest level of antioxidant and antimicrobial action on it. These potentially optimistic biological screening results for synthetic derivatives will provide a solid basis in this field, perhaps paving the way for the establishment of new therapeutic agents.

CONSENT

This article does not contain any studies with human participants or animals performed by any of the authors. Formal consent is not needed for this type of investigation.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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