Journal of Chemical Health Risks

www.jchr.org

JCHR (2026) 16(2), 4041-4047 | ISSN:2251-6727

Design, Synthesis and Spectral Characterization of Novel Quinazolinone–Thiazole Hybrid Molecules with Promising Antibacterial and Antifungal Properties

Bulakhe Bhau Ashok[1,*], L.R. Patil[1], D.G. Karpe[2] and N.M. Thorat[1]

[1]Department of Chemistry, Maharaja Jivajirao Shinde Mahavidyalaya, Shrigonda-413701, INDIA

[2]Department of Chemistry, Shri Chhatrapati Shivaji Mahavidyalaya, Shrigonda-413701, INDIA

(Received: 16 February 2026 Revised: 25 March 2026 Accepted: 10 April 2026)

KEYWORDS

Heterocyclic compounds
Quinazolinone–thiazole derivatives
Hantzsch reaction
Biological activities

ABSTRACT:

A series of novel quinazolinone–thiazole hybrid derivatives (**5a-e**) were designed and synthesised through a multistep synthetic protocol involving quinazolinone formation, Hantzsch thiazole cyclization and final condensation under reflux conditions. The obtained compounds were isolated in good yields and fully characterised by IR, ^{1}H NMR, EI-MS and elemental analysis, which confirmed the successful formation of the targeted molecular framework. Spectral studies revealed characteristic absorption bands for lactam carbonyl and azomethine functionalities, while NMR and mass data supported the proposed substitution patterns. The antimicrobial potential of the synthesised hybrids was evaluated *in vitro* against Gram-positive bacteria (*Enterococcus faecalis*, *Micrococcus luteus*), Gram-negative bacteria (*Klebsiella pneumoniae*, *Proteus mirabilis*) and fungal strains (*Candida tropicalis*, *Aspergillus niger*) using the agar well diffusion method. The synthesized compounds exhibited moderate to good broad-spectrum activity with inhibition zones ranging from 10 to 22 mm. Derivatives **5a** and **5e** showed the highest antibacterial activity, particularly against Gram-positive strains, while 5c displayed the best antifungal activity against *C. tropicalis*. It is found that electron-withdrawing substituents in the quinazolinone–thiazole hybrids enhanced antimicrobial potency and lead as promising compounds for further antimicrobial drug development.

1. Introduction

Nitrogen- and sulfur-containing heterocyclic compounds constitute one of the most important classes of scaffolds in medicinal chemistry due to their structural diversity and wide range of biological activities. Among them, quinazolinones are recognized as privileged bicyclic systems that occur in numerous bioactive molecules and approved drugs. The quinazolinone nucleus is associated with a broad spectrum of pharmacological properties including anticancer, antimicrobial, anti-inflammatory, anticonvulsant and antiviral activities, making it a key scaffold for the drug discovery programs [1-3]. The rigid fused bicyclic structure enables multiple non-covalent interactions such as hydrogen bonding, π–π stacking and hydrophobic contacts with biological targets, which enhances receptor binding affinity and selectivity [4,5].

Similarly, thiazole-based heterocycles represent another highly significant pharmacophore in medicinal chemistry. The presence of nitrogen and sulfur atoms in a five-membered aromatic ring confers unique electronic properties, allowing thiazoles to mimic biologically relevant heterocycles such as histidine and imidazole [6]. Thiazole derivatives exhibit diverse biological activities including antimicrobial, antifungal, antitubercular, anticancer, anti-inflammatory, antioxidant and antiviral effects [7-10]. Their ability to improve lipophilicity, metabolic stability and target binding makes them valuable fragments in drug design, particularly in the development of antimicrobial agents against resistant strains.

A modern and powerful approach in medicinal chemistry is molecular hybridization, where two or more pharmacophores are combined into a single molecular framework to enhance biological activity and reduce drug resistance. Quinazolinone–thiazole hybrids are of particular interest due to the complementary pharmacological profiles of both scaffolds. Such hybrid molecules often exhibit improved potency, dual-target activity, and enhanced pharmacokinetic properties compared to their parent compounds [11-13]. This strategy has been widely employed in the design of antimicrobial and anticancer agents.

Journal of Chemical Health Risks
www.jchr.org
JCHR (2026) 16(2), 4041-4047 | ISSN:2251-6727

Despite their promising bioactivities, conventional synthetic routes toward heterocyclic hybrids often suffer from limitations such as multistep synthesis, toxic reaction conditions, poor atom economy, long reaction times, and environmental concerns associated with toxic solvents and catalysts. These limitations contradict the principles of green chemistry and sustainable synthesis [14,15]. Therefore, the development of efficient, eco-friendly and operationally simple synthetic methodologies remains highly desirable. In this context, multicomponent reactions (MCRs) have emerged as a powerful synthetic strategy for the rapid construction of complex heterocyclic frameworks. MCRs offer significant advantages such as high atom economy, reduced waste generation, operational simplicity and structural diversity in a single synthetic step [16,17]. Moreover, mild catalytic systems such as iodine-mediated transformations provide environmentally benign alternatives to the traditional harsh reagents, facilitating efficient cyclization and condensation processes.

In addition, the incorporation of green chemistry tools such as solvent minimization, mild temperature conditions and MCRs strategies significantly enhances the sustainability of heterocyclic synthesis [18,19]. Recent advances have demonstrated that I_2-catalyzed and acid assisted multicomponent reactions are highly effective for constructing fused heterocyclic systems with improved yields and reduced reaction times [20,21].

Building upon these developments, the present study reports the synthesis, characterization and biological evaluation of novel quinazolinone-thiazole hybrid molecules *via* a one-pot multicomponent strategy under mild conditions. The synthetic design integrates quinazolinone and thiazole pharmacophores into a single molecular architecture, aiming to explore potential synergistic biological effects. Structural diversity is introduced through various substituted aromatic aldehydes enabling systematic investigation of structure–activity relationships (SAR), particularly electronic and steric influences on the biological performance.

2. Experimental

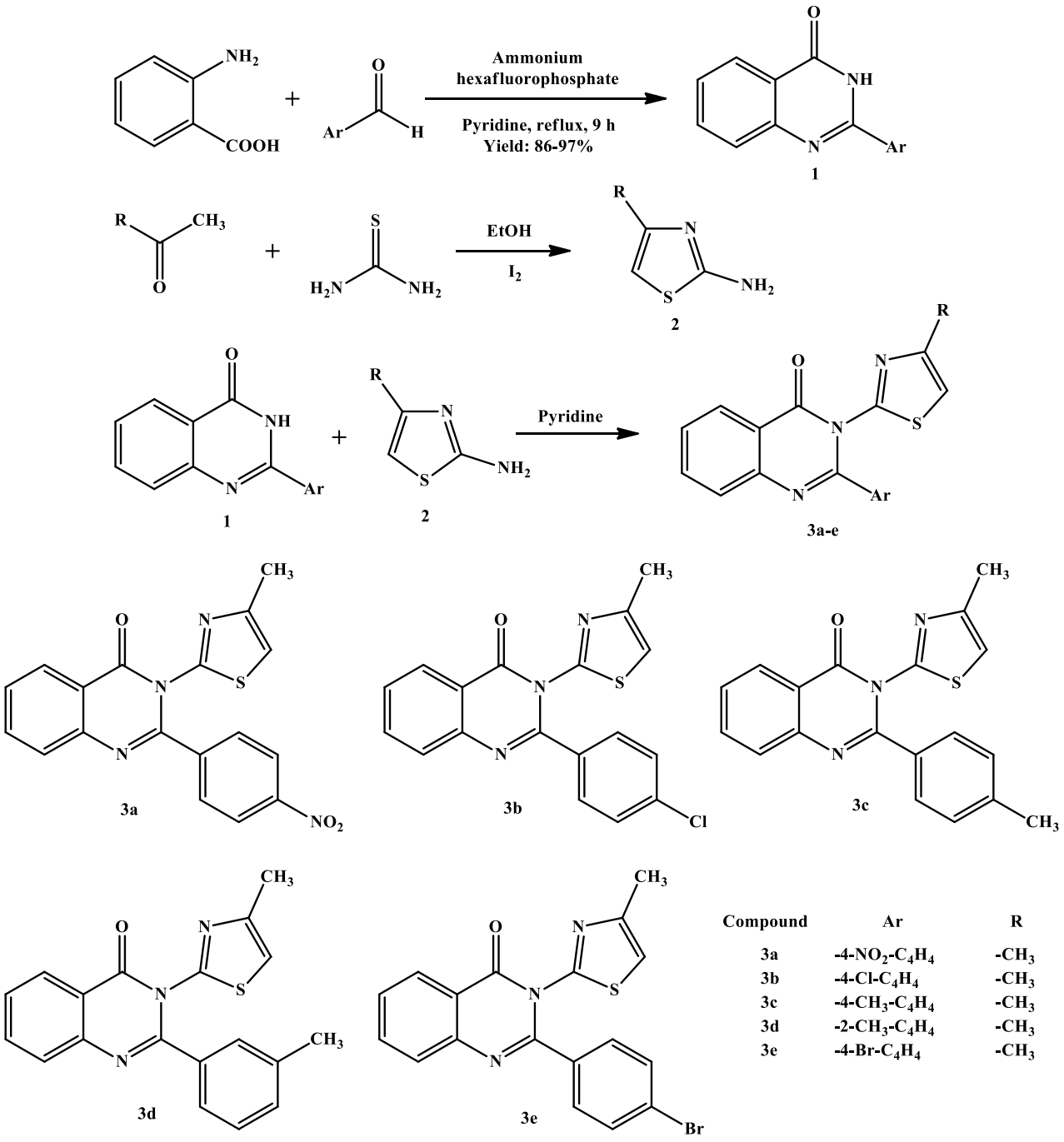
All chemicals and reagents employed in this study were procured from commercial suppliers and used without further purification. The progress of the reactions and the purity of the synthesized compounds were monitored by thin-layer chromatography (TLC) using silica gel 60 GF_{254} pre-coated aluminium plates (Merck). A solvent system comprising ethyl acetate and benzene was used as the mobile phase and the developed spots were visualized under iodine vapour. Melting points of the synthesized compounds were determined using an open capillary method and are reported uncorrected. The structural characterization of the synthesized molecules was carried out using standard spectroscopic techniques. Infrared (IR) spectra were recorded as potassium bromide (KBr) pellets on a PerkinElmer RX IFT-IR spectrophotometer. Proton (^1H) and carbon (^{13}C) nuclear magnetic resonance (NMR) spectra were acquired on a Bruker AVANCE II 400 MHz spectrometer using deuterated solvents. Elemental (CHN) analysis was performed using a Vario Micro CHN analyzer and the obtained values were found to be in good agreement with theoretical calculations, within an acceptable deviation of ±0.4%.

Synthesis of quinazolinone-thiazoles (3a-e): In the synthesis of novel quinazolinone-thiazole hybrid molecules, in the first step, a mixture containing 2-aminobenzoic acid (1.37 g, 10 mmol), the corresponding carboxylic acid (1.34 g, 11 mmol), ammonium hexafluorophosphate (1.79 g, 11 mmol) and pyridine (10 mL) was introduced into a dry 50 mL round-bottom flask fitted with a reflux condenser and a Teflon-coated magnetic stir bar. The reaction mixture was heated under reflux with continuous stirring for 9 h. Upon completion, pyridine was removed under reduced pressure using a rotary evaporator, and the resulting product **1** was purified through recrystallization from ethanol. Then in a second step, the reaction follows a Hantzsch thiazole synthesis pathway, where an α-haloketone reacts with thiourea to form a 2-aminothiazole derivative through substitution, cyclization and oxidation. First, thiourea attacks the electrophilic α-carbon of α-haloketone, displacing the halogen and forming an S-alkyl thiouronium intermediate followed by the occurrence of intramolecular cyclization when the amino nitrogen attacks the adjacent carbonyl carbon, leading to closure of the five membered thiazole ring **2**. Here, I_2 acts as a mild oxidizing agent, removing hydrogen atoms and restoring conjugation to produce the aromatic thiazole system. Finally, in a round bottom flask, compound **1** (0.012 mol) and compound **2** (0.01 mol) were dissolved in pyridine (50 mL), and the resulting mixture was heated under reflux for 8-9 hours. The reaction progress was monitored at regular intervals. After completion, the mixture was poured into ice-cold water and subsequently acidified with 10% dilute HCl to eliminate impurities. The precipitated solid was collected

Journal of Chemical Health Risks
www.jchr.org
JCHR (2026) 16(2), 4041-4047 | ISSN:2251-6727

by filtration, washed with cold water, and finally purified by recrystallization from ethanol (**Scheme-I**).

2-(4-Nitrophenyl)-3-(5-methylthiazol-2-yl)quinazolin-4(3*H*)-one (3a): White solid, yield (0.78 g); m.p. 266-268 ºC. IR (KBr, ν_{max}, cm^{-1}): 1645 (C=O), 1575 (C=N), 1520 (aromatic C=C/NO_2 asym. *str.*), 1301 (C–H *bend.*), 1245 (C–O), 1234 (C–N/C–C), 834, 756, 681 (arom. C–H out-of-plane bending); ^{1}H NMR (300 MHz, $CDCl_3$, δ ppm): 8.28 (d, 1H, *J* = 8.5 Hz), 8.12 (d, 2H, *J* = 8.5 Hz, Ar–H), 8.06 (d, 1H, *J* = 7.9 Hz), 7.63 (d, 2H, *J* = 7.8 Hz, Ar–H), 7.49 (t, 1H, *J* = 7.3 Hz), 7.13 (t, 1H, *J* = 7.7 Hz), 7.01 (s, 1H, thiazole-H), 2.42 (s, 3H, CH_3); EI-MS (*m/z*, %): 364 (M^+), 333, 308, 295,



Compound	Ar	R
3a	-4-NO_2-C_4H_4	-CH_3
3b	-4-Cl-C_4H_4	-CH_3
3c	-4-CH_3-C_4H_4	-CH_3
3d	-2-CH_3-C_4H_4	-CH_3
3e	-4-Br-C_4H_4	-CH_3

Scheme-I: Synthetic route of Novel Quinazolinone–Thiazole Hybrid Molecules (3a-e)

Journal of Chemical Health Risks
www.jchr.org
JCHR (2026) 16(2), 4041-4047 | ISSN:2251-6727

281, 267, 253, 145, 132, 120, 105 (base peak). Anal. calcd. (found) % for $C_{18}H_{14}N_4O_3S$: calcd. (found) %: C, 59.34 (59.21); H, 3.32 (3.28); N, 15.38 (15.24); S, 8.80 (8.67).

2-(4-Chlorophenyl)-3-(5-methylthiazol-2-yl)quinazolin-4(3H)-one (3b): Yellow solid; yield (0.82 g); m.p. 226-228 ºC. IR (KBr, ν_{max}, cm^{-1}): 1650 (C=O), 1582 (C=N), 1518 (arom. C=C), 1310 (C–H *bend.*), 1248 (C–O/C–N), 1092 (C–Cl), 835, 758, 690 (arom. C–H out-of-plane *bend.*); ^{1}H NMR (300 MHz, $CDCl_3$, δ ppm): 8.24 (d, 1H, *J* = 8.4 Hz), 8.08 (d, 1H, *J* = 7.8 Hz), 7.92 (d, 2H, *J* = 8.5 Hz, Ar–H), 7.55 (d, 2H, *J* = 8.5 Hz, Ar–H), 7.46 (t, 1H, *J* = 7.4 Hz), 7.11 (t, 1H, *J* = 7.6 Hz), 6.98 (s, 1H, thiazole-H), 2.40 (s, 3H, CH_3); EI-MS (*m/z*, %): 353 (M^+), 355 (M+2, Cl isotope), 318, 290, 267, 253, 145, 132, 120, 105 (base peak); Anal. calcd. (found) % for $C_{18}H_{12}N_3OSCl$: C, 61.45 (61.32); H, 3.44 (3.39); N, 11.94 (11.88); S, 9.11 (9.04).

2-(4-Methylphenyl)-3-(5-methylthiazol-2-yl)quinazolin-4(3*H*)-one (3c): White solid; yield (0.85 g); m.p. 218-220 ºC; IR (KBr, ν_{max}, cm^{-1}): 1648 (C=O), 1580 (C=N), 1515 (arom. C=C), 1305 (C–H *bend.*), 1242 (C–O/C–N), 835, 760, 695 (arom. C–H out-of-plane *bend.*), 2920 (CH_3 *str.*); ^{1}H NMR (300 MHz, $CDCl_3$, δ ppm): 8.22 (d, 1H, *J* = 8.3 Hz), 8.05 (d, 1H, *J* = 7.8 Hz), 7.82 (d, 2H, *J* = 8.1 Hz, Ar–H), 7.32 (d, 2H, *J* = 8.1 Hz, Ar–H), 7.44 (t, 1H, *J* = 7.3 Hz), 7.10 (t, 1H, *J* = 7.6 Hz), 6.96 (s, 1H, thiazole-H), 2.41 (s, 3H, thiazole-CH_3), 2.34 (s, 3H, Ar-CH_3); EI-MS (*m/z*, %): 333 (M^+), 318, 304, 290, 267, 253, 145, 132, 120, 105 (base peak); Anal. calcd. (found) % for $C_{19}H_{15}N_3OS$: C, 68.45 (68.31); H, 4.54 (4.49); N, 12.60 (12.52); S, 9.62 (9.55).

2-(3-Methylphenyl)-3-(5-methylthiazol-2-yl)quinazolin-4(3H)-one (3d): White solid; yield (0.86 g); m.p. 214-216 ºC. IR (KBr, ν_{max}, cm^{-1}): 1647 (C=O), 1578 (C=N), 1516 (aromatic C=C), 1304 (C–H bending), 1240 (C–O/C–N), 2922 (CH_3 *str.*), 836, 758, 694 (arom. C–H out-of-plane *bend.*); ^{1}H NMR (300 MHz, $CDCl_3$, δ ppm): 8.23 (d, 1H, *J* = 8.4 Hz), 8.06 (d, 1H, *J* = 7.9 Hz), 7.70-7.62 (m, 2H, Ar–H), 7.42 (t, 1H, *J* = 7.4 Hz), 7.34-7.26 (m, 2H, Ar–H), 7.11 (t, 1H, *J* = 7.6 Hz), 6.97 (s, 1H, thiazole-H), 2.42 (s, 3H, thiazole-CH_3), 2.36 (s, 3H, Ar-CH_3); EI-MS (*m/z*, %): 333 (M^+), 318, 304, 290, 267, 253, 145, 132, 120, 105 (base peak); Anal. calcd. (found) % for $C_{19}H_{15}N_3OS$: C, 68.45 (68.30); H, 4.54 (4.47); N, 12.60 (12.55); S, 9.62 (9.58).

2-(4-Bromophenyl)-3-(5-methylthiazol-2-yl)quinazolin-4(3H)-one (3e): Yellow; yield (0.88 g); m.p. 236-238 ºC. IR (KBr, ν_{max}, cm^{-1}): 1651 (C=O), 1581 (C=N), 1517 (arom. C=C), 1308 (C–H *bend.*), 1246 (C–O/C–N), 1070 (C–Br), 836, 760, 688 (arom. C–H out-of-plane *bend.*); ^{1}H NMR (300 MHz, $CDCl_3$, δ ppm): 8.25 (d, 1H, *J* = 8.4 Hz), 8.07 (d, 1H, *J* = 7.9 Hz), 7.88 (d, 2H, *J* = 8.4 Hz, Ar–H), 7.60 (d, 2H, *J* = 8.4 Hz, Ar–H), 7.45 (t, 1H, *J* = 7.4 Hz), 7.12 (t, 1H, *J* = 7.6 Hz), 6.99 (s, 1H, thiazole-H), 2.41 (s, 3H, CH_3); EI-MS (*m/z*, %): 397 (M^+), 399 (M+2, Br isotope), 318, 290, 267, 253, 145, 132, 120, 105 (base peak); Anal. calcd. (found) % for $C_{18}H_{12}N_3OSBr$: C, 54.28 (54.15); H, 3.04 (2.98); N, 10.55 (10.49); S, 8.05 (7.98).

2.2 Biological activities: Quinazolinone–thiazole hybrid derivatives (**3a-e**) were evaluated for their *in vitro* antimicrobial activity against a panel of pathogenic microorganisms, including Gram-negative bacteria (*Klebsiella pneumoniae, Proteus mirabilis*), Gram-positive bacteria (*Enterococcus faecalis*, *Micrococcus luteus*), and fungal strains (*Candida tropicalis*, *Aspergillus niger*), using the agar well diffusion method. Dimethyl sulfoxide (DMSO) was used as the negative control. Ciprofloxacin served as the reference standard for antibacterial activity, while fluconazole was used as the standard antifungal agent. Briefly, microbial suspensions (100 µL, ~10^{-4} CFU/mL) were uniformly spread onto sterile nutrient agar plates. Wells were then bored into the agar and filled with test compounds at different concentrations. The plates were incubated at 37 ºC for 24 h for bacterial cultures and at 27 ºC for 96 h for fungal strains. Antimicrobial activity was assessed by measuring the zones of inhibition (mm) around each well. The minimum inhibitory concentration (MIC) was determined as the lowest concentration of compound that completely inhibited visible microbial growth.

3. Results and Discussion

Novel quinazolinone–thiazole hybrid molecules were synthesised through a three-step route. Initially, 2-aminobenzoic acid and the appropriate carboxylic acid were refluxed in pyridine in the presence of ammonium hexafluorophosphate to afford the corresponding quinazolin-4(3*H*)-one intermediate (**1**), which was isolated after solvent removal and recrystallisation. In the second step, the thiazole intermediate (**2**) was prepared *via* a Hantzsch thiazole synthesis, where thiourea reacted with the α-haloketone through nucleophilic substitution, cyclization and iodine-assisted oxidation to generate the aromatic 2-aminothiazole ring. Finally, condensation of compounds **1** and **2** in refluxing pyridine for 8-9 h furnished the target quinazolinone–thiazole hybrids. The reaction mixture was poured into ice-cold water, acidified with dilute HCl and the precipitated products were filtered,

Journal of Chemical Health Risks
www.jchr.org
JCHR (2026) 16(2), 4041-4047 | ISSN:2251-6727

washed and recrystallised from ethanol to obtain pure final compounds (**Scheme-I**).

The structures of compounds **3a-e** were confirmed by combined IR, ^{1}H NMR, mass spectrometric and elemental analytical data, all of which are consistent with the proposed quinazolinone–thiazole hybrid framework. In the IR spectra, all derivatives exhibited a strong absorption band in the region 1645-1651 cm^{-1}, characteristic of the lactam C=O stretching vibration of the quinazolin-4(3*H*)-one ring. The peaks observed at 1575-1582 cm^{-1} were assigned to C=N stretching of the quinazoline/thiazole heterocyclic system, while absorptions near 1515-1520 cm^{-1} correspond to the aromatic skeletal vibrations. Compound **3a** additionally showed an enhanced band in this region attributable to the asymmetric stretching of the NO_2 group. Signals in the range 1240-1248 cm^{-1} were associated with C–O/C–N stretching vibrations, whereas characteristic substituent bands such as C–Cl (1092 cm^{-1}), C–Br (1070 cm^{-1}) and methyl C–H stretching near 2920-2922 cm^{-1} for methyl-substituted derivatives further supported successful substitution. Aromatic C–H out-of-plane bending vibrations appeared between 688-836 cm^{-1}. The ^{1}H NMR spectra of all compounds showed a consistent pattern for the fused heterocyclic scaffold. Aromatic protons of the quinazolinone nucleus and substituted phenyl ring resonated in the downfield region δ 7.10-8.28 ppm, with multiplicities matching the expected substitution pattern. *para*-Substituted derivatives **3a**, **3b**, **3c**, and **3e** displayed two doublets for the phenyl ring protons, while the *meta*-substituted derivative **3d** exhibited a more complex multiplet pattern. A characteristic singlet at δ 6.96-7.01 ppm in all compounds was assigned to the isolated thiazole C4–H proton, confirming formation of the thiazole ring. The methyl group attached to the thiazole ring appeared as a singlet near δ 2.40-2.42 ppm, whereas aryl methyl substituents in compounds **3c** and **3d** resonated separately at δ 2.34-2.36 ppm.

Electron impact mass spectra further established the molecular composition. Each compound showed a clear molecular ion peak corresponding to its expected molecular mass *m/z* 364 (**3a**), 353 (**3b**), 333 (**3c** and **3d**) and 397 (**3e**). Halogenated derivatives displayed the expected isotopic patterns, with M/M+2 peaks for chlorine in **3b** and bromine in **3e**, confirming the presence of these substituents. Fragmentation peaks common to the series arose from cleavage of the thiazole and aryl substituents, while intense lower-mass fragments supported stability of the quinazolinone core. Thus, based on the spectral evidence conclusively verifies successful synthesis of the targeted substituted quinazolinone–thiazole hybrids.

Antimicrobial activities: The quinazolinone–thiazole hybrid derivatives (**3a-e**) exhibited moderate to good broad spectrum antimicrobial activity, with inhibition zones ranging from 10 to 22 mm (Table-1), indicating that the synthesized scaffold possesses appreciable biological potential against both bacterial and fungal strains. Among the tested compounds, **3a** and **3e** emerged as the most active antibacterial agents, particularly against Gram-positive organisms. Compound **3a** showed the highest activity against *E. faecalis* (22 mm) and *M. luteus* (21 mm), while compound **3e** also demonstrated strong inhibition (21 mm and 20 mm, respectively). This enhanced susceptibility of Gram-positive bacteria can be attributed to the absence of an outer lipopolysaccharide membrane, which facilitates easier penetration of bioactive molecules and allows better interaction with intracellular targets [22]. In contrast, Gram-negative bacteria (*K. pneumoniae* and *P. mirabilis*) exhibited comparatively lower sensitivity, with inhibition zones ranging from 10-16 mm. This reduced activity is consistent with the well-known structural barrier

TABLE-1
ANTIBACTERIAL AND ANTIFUNGAL RESULTS OF NOVEL QUINAZOLINONE–THIAZOLE MOLECULES

Compound	Zone of inhibition (mm)					
	K. pneumoniae	*P. mirabilis*	*E. faecalis*	*M. luteus*	*C. tropicalis*	*A. niger*
3a	16	15	22	21	18	17
3b	14	13	18	17	15	13
3c	12	11	17	16	19	16
3d	11	10	16	15	14	12
3e	15	14	21	20	16	15

of Gram-negative bacteria, where the outer membrane

Journal of Chemical Health Risks

www.jchr.org

JCHR (2026) 16(2), 4041-4047 | ISSN:2251-6727

limits diffusion of hydrophobic and bulky heterocyclic compounds, thereby decreasing intracellular accumulation and efficacy. In antifungal evaluation, compound **3c** exhibited the highest activity against *C. tropicalis* (19 mm), suggesting that specific structural features in compound **3c** may favour interaction with fungal cellular components, possibly through membrane disruption or enzyme inhibition. Compound **3a** showed the most pronounced antifungal effect against *A. niger* (17 mm), indicating that this derivative possesses relatively balanced antibacterial and antifungal properties.

A clear trend can be observed across the series of the synthesized compounds. Compounds bearing electron-withdrawing substituents (*e.g.* halogens or nitro groups in analogous systems) generally exhibited enhanced antimicrobial activity compared to electron-donating groups. This can be rationalized by increased lipophilicity and improved membrane permeability, which facilitate better penetration into microbial cells and stronger binding interactions with biological targets such as enzymes or nucleic acids [23]. Based on these results, it is concluded that the quinazolinone–thiazole hybrid framework is a promising scaffold for antimicrobial development, with compounds **3a** and **3e** identified as lead candidates for further optimization and mechanistic studies.

Conclusion

A new series of quinazolinone–thiazole hybrid compounds (**3a-e**) was successfully synthesised and structurally validated using standard spectroscopic and analytical techniques. The developed synthetic route afforded the target compounds in satisfactory yields with good purity. The biological screening demonstrated that the hybrids possess notable antimicrobial activity against both bacterial and fungal pathogens. Compounds **3a** and **3e** emerged as the most effective antibacterial derivatives, whereas compound **3c** showed superior antifungal performance. The results suggest that incorporation of electron-withdrawing groups positively influences biological activity. The quinazolinone–thiazole scaffold represents a valuable platform for future structural modification and optimisation toward potent antimicrobial agents.

References

1. A. Kalakwade, R.S. Kavalapure, S. Gharge, S.G. Alegaon, S.D. Ranade, L.S. Wong and R. Ramu, Heterocyclic compounds with diverse biological activities: A review of quinazoline and quinazolinone derivatives, *Results in Chemistry*, **19**, 102932 (2026); doi: 10.1016/j.rechem.2025.102932.
2. R. Jamgade, Quinazolinone derivatives represent a vital class of heterocyclic compounds known for their structural diversity and wide-ranging biological activities, *International Journal of Pharmaceutical Sciences*, **3**, 5604 (2025); doi: 10.5281/zenodo.15766260
3. P.C. Sharma, G. Kaur, R. Pahwa, A. Sharma and H. Rajak, Quinazolinone analogs as potential therapeutic agents, *Current Medicinal Chemistry*, **18**, 4786 (2011); doi: 10.2174/092986711797535326
4. D. Shah and A. Patel, Imidazo[1,2-a]pyridine derivatives as promising anticancer agents: Synthesis and therapeutic potential, *Archiv der Pharmazie*, **359**, e70214 (2026); doi: 10.1002/ardp.70214
5. S.B. Bharate, R.A.M. Vishwakarma and R.A. Bharate, Quinazolinone derivatives as promising therapeutic agents, *European Journal of Medicinal Chemistry*, **63**, 435 (2013); doi: 10.1016/j.ejmech.2013.02.024.
6. M.F. Arshad, A. Alam, A.A. Alshammari, M.B. Alhazza, I.M. Alzimam, M.A. Alam, G. Mustafa, M.S. Ansari, A.M. Alotaibi, A.A. Alotaibi, S. Kumar, S.M.B. Asdaq, M. Imran, P.K. Deb, K.N. Venugopala and S. Jomah, Thiazole: A versatile standalone moiety contributing to the development of various drugs and biologically active agents, *Molecules*, **27**, 3994 (2022); doi: 10.3390/molecules27133994
7. D.N. Thorat, K.S. Sonar, S.R. Kale, A. Singh, S.D. Patil and P. Awasthi, A comprehensive review on thiazole derivatives as multifunctional therapeutics, *Discovery Chemistry*, **3**, 88 (2026); doi: 10.1007/s44371-026-00550-7
8. A. Singh, D. Malhotra, K. Singh, R. Chadha and P.M. S. Bedi, Thiazole derivatives in medicinal chemistry: Recent advancements in synthetic strategies, structure activity relationship and pharmacological outcomes, *Journal of Molecular Structure*, **1266**, 133479 (2022); doi: 10.1016/j.molstruc.2022.133479
9. A. Rusu, I.-M. Moga, L. Uncu and G. Hancu, The role of five-membered heterocycles in the molecular structure of antibacterial drugs used in therapy, *Pharmaceutics*, **15**, 2554 (2023); doi: 10.3390/pharmaceutics15112554
10. M. Kashyap, M.U. Mazumder, P. Patowary, B.J. Sahariah, A. Talukdar and M. Majumder, An over-

view of synthetic derivatives of thiazole and their role in therapeutics, *FABAD J. Pharm. Sci*., **49**, 603 (2024); doi: 10.55262/fabadeczacilik.1479735

11. S.G. Hammad, D.S. Aboul-Magd, M.M. Ghorab, M. Adel, R.A.T. Serya, E.M. El-Hossary, M.G. El-Gazzar and K.A.M. Abouzid, Ligand-based design of novel thiazole-quinazolinone hybrids with dual antimicrobial and anti-virulence activity targeting *staphylococcal sortase* A, *Bioorganic & Medicinal Chemistry*, **136**, 118576 (2026); doi: 10.1016/j.bmc.2026.118576
12. A. Şandor, I. Fizeşan, I. Ionuţ, G. Marc, I. Oniga, C. Moldovan, A. Pîrnău, L. Vlase, A.-E. Petru, I. Macasoi and O. Oniga, Discovery of a novel series of quinazoline-thiazole hybrids as potential antiproliferative and anti-angiogenic agents, *Biomolecules*, **14**, 218 (2024); doi: 10.3390/biom14020218
13. S. Jaiswal, K. Verma, A. Srivastva, J. Dwivedi, N. Arya and S. Sharma, Green synthetic and pharmacological developments in hybrid quinazolinone moiety: An Updated review, *Current Organic Chemistry*, **25**, 493 (2025); doi: 10.2174/0115680266313354240807051401
14. K.K. Patel, Design and synthesis of eco-friendly heterocyclic compounds using bio-based catalysts: A sustainable approach to drug discovery, *International Journal of Scientific Research in Chemistry*, **10**, 23 (2023); doi: 10.32628/IJSRCH
15. A. Farasrami, Recent Advances in Eco-Friendly Synthetic Approaches for Heterocyclic Compounds: Targeting Type-2 Diabetes and Beyond *International Journal of Pharmaceutical Sciences*, **2**, 109 (2024); 10.5281/zenodo.13629409
16. D. Insuasty, J. Castillo, D. Becerra, H. Rojas and R. Abonia, Synthesis of biologically active molecules through multicomponent reactions, *Molecules*, **25**, 505 (2020); doi: 10.3390/molecules25030505
17. S. Naik, R. Bharti and R. Sharma, Eco-friendly heterocyclic synthesis *via* multicomponent reactions using solid base catalysts: An overview, *Current Organic Chemistry*, **29**, 1580 (2025); doi: 10.2174/0113852728364378250403062328
18. M.-Y. Li, A. Gu, J. Li and Y. Liu, Advanced green synthesis: Solvent-free and catalyst-free reaction," Green Synthesis and Catalysis, **6**, 36 (2025); doi: 10.1016/j.gresc.2024.11.001
19. X. Shen, G. Hong, and L. Wang, Recent advances in green multi-component reactions for heterocyclic compound construction, *Organic & Biomolecular Chemistry*, **23**, 2059 (2025); doi: 10.1039/D4OB01822B
20. Z. Malinowski, Recent advances in one-pot multicomponent reactions for the synthesis of substituted quinazolin-4(3H)-ones, *Molecules*, **30**, 3729 (2025); doi: 10.3390/molecules30183729
21. H. Bisharat, S. Javaid, Z. Ahmad, S. Mahmood, A. Saeed and D. Khan, Recent advances in green catalytic multicomponent reactions for sustainable synthesis, *ChemistrySelect*, 11, e06024 (2026); doi: 10.1002/slct.202506024
22. T.M. Uddin, A.J. Chakraborty, A. Khusro, B.M.R. M. Zidan, S. Mitra, T.B. Emran, K. Dhama, M.K.H. Ripon, M. Gajdács, M.U.K. Sahibzada, M.J. Hossain and N. Koirala, Antibiotic resistance in microbes: History, mechanisms, therapeutic strategies and future prospects, *Journal of Infection and Public Health*, **14**, 1750 (2021); doi: 10.1016/j.jiph.2021.10.020
23. I.C. Marinas, N. Simionescu, N.D. Andreiu, A. Al-Matarneh, T. Pinteala, M.C. Chifiriuc and C.M. Al-Matarneh, Influence of substitution patterns on the antimicrobial properties of pyrrole sulfonamide scaffolds, *Frontiers in Chemistry*, **14**, 1726389 (2026); doi: 10.3389/fchem.2026.1726389