

# Antibacterial Activity of Thiazole and its Derivatives: A Review

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**Abstract:** Thiazoles are one of the most intensively scrutinized classes of 5-membered aromatic heterocycles. Many natural and synthesized thiazole and its derivatives showed significant biological activity. Due to its unique properties, thiazole derivatives show significant antibacterial activity against various bacteria and pathogens. Thus, the present review ascribes the antibacterial activity of various thiazole and its derivatives. From using various databases, all the relevant literature has been reviewed. The review was deliberated based on the significant papers on the antibacterial activity of thiazole derivatives. Thiazole and its derivatives, a significant class of heterocyclic derivatives, have played an important role in chemical sciences. Due to their unique properties, they play an important role in the pharmaceutical industry. Thiazole and its derivatives show significant anticancer, anti-tuberculous, antioxidant, and anti-inflammatory activities. Due to their tremendous biological significance, scientists are actively engaged in designing new biological active thiazole derivatives. This review emphasized the antibacterial properties of various thiazole and its derivatives. The present study will help researchers design and synthesize various biological active molecular probes and study their antibacterial properties using various processes against various bacteria and pathogens.

**Keywords:** thiazole; antibacterial; bacteria; pathogen.

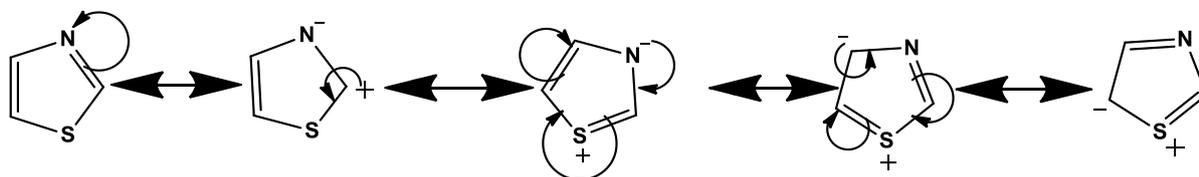
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## 1. Introduction

In the clinical world, consideration of retardation of pathogenic bacteria towards the available antibiotic was becoming a major worldwide problem as many bacterial pathogens have already established resistance against them [1-6]. Therefore, there could be the appearance of increasing in the mortality rate for gram-positive and/or gram-negative bacterial diseases. It is mainly due to the over-growth in population and extreme modernization for comfort. Hence, the rapid development of microbial resistance leads to discovering a new effective antimicrobial drug agent, which can reduce the bacterial mortality rate [7-12]. To set up a revolutionary change in the failure of synthesizing selective antibacterial drugs, researchers have been endeavored by a lot of eminent expertise from last few decades. To achieve a new effective scaffold for an efficient fight against bacterial viruses is required. The research on the development of new antimicrobial agents has mainly focused on two aspects like increasing potent bacterial antigen drugs and the appearance of new bacteria pathogen. The main aspect of synthesizing effective drugs is their structural characteristic and the rate of activity. Initially, there has been consideration of a heterocyclic compound as a parent

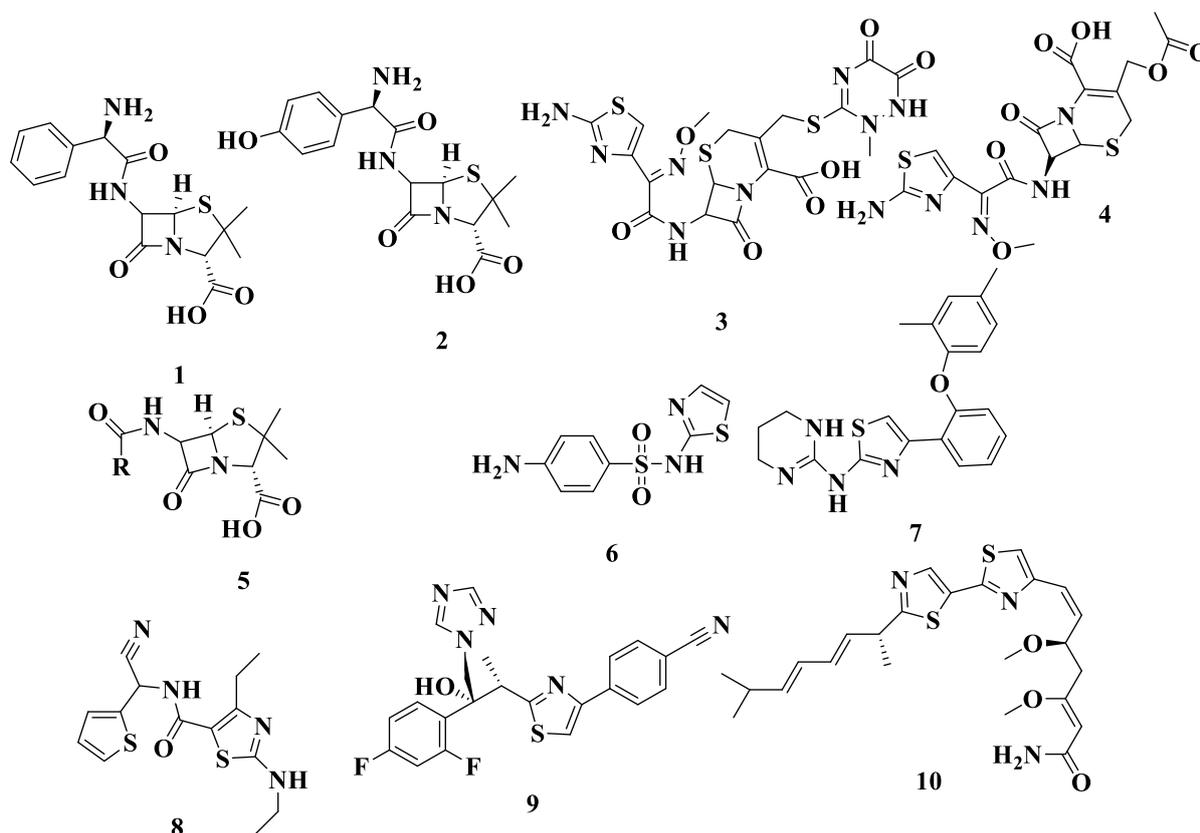
compound to synthesize the effective antibacterial drug. The assessment of those vast antimicrobial literature data admits that heterocyclic compound has played a vital role in the clinical field [13-18]. Therefore, in the field of pharmacology, heterocycles are very popular for their unique controlling properties within a drug, such as a solubility, lipophilicity, and polarity, and are also being investigated several times for the discovery of desired active drugs [19-21].

The fascinating biological significance of antibacterial pathogens has led to the urgency for drug discovery and the synthesis of new antimicrobial compounds. Thiazoles are one of the most intensively scrutinized classes of 5-membered aromatic heterocycles. Large extent research on thiazole ring from the past two to three decades has proven that the thiazole scaffold has various active biological properties such as antioxidant, antibacterial, anti-viral, diuretic, antitumor and anti-convulsing properties [2223]. Thiazole has an electron-donating group (-S-) and an electron-accepting group (-N-). The aromaticity of thiazole was only due to the delocalization of a non-bonding pair of electrons from the sulfur atom to fulfill the vacant 6p electrons to fulfill Hackle's rule (Scheme-1).



**Scheme 1.** Resonating structure of thiazole.

Divergent moderation of the thiazole ring at various positions led to various novel compounds with a wide spectrum of biological activities. Due to biological activity and availability in nature, heterocyclic thiazole compound plays a vital role in the clinical field to treat various bacterial infections in the human body [2425]. This type of biological investigation takes us to a new world of research to synthesize newly novel derivatives with strong biological activity. The past few years have proved a remarkable decrease in the mortality rate caused by a bacterial disease. The urgency of detecting the active pathogenic bacterial resistance creates a new researched field of synthesizing the novel thiazole derivatives as a potent antibacterial agent. The thiazole nucleus is an active nucleus as thiazole-containing compounds offer a wide range of applications as pharmacological agents. Hantzsch and weber first described it in 1887. Antibiotic such as Penicillin (5), Ceftriaxone (3), Ampicillin (1), Cefotaxime (4), Amoxicillin (2), antimicrobials such as Myxothiazole (10), sulfathiazole (6), Ethaboxam (8), Abafungin (7), Ravuconazole (9) and have thiazole nucleus (Figure 1). Thiazole is mostly found in vitamins [26-28]. The most important naturally occurring thiazole derivative is thiamine (vitamin B1). Various natural food flavors and aroma consisting of thiazole nucleus. The literature review recommended that thiazole derivatives have fascinated the interest of chemists in the field of drugs and pharmaceuticals [29-31]. All this information was active strength to grow new thiazole derivatives with a broad structural variation. Hence, this present review recaps the effect of various substituents in thiazole heterocyclic rings to develop novel thiazole derivatives for antibacterial potential in different cell lines by analyzing the structure-activity relationship and mechanism of action of a wide range of derivatives.

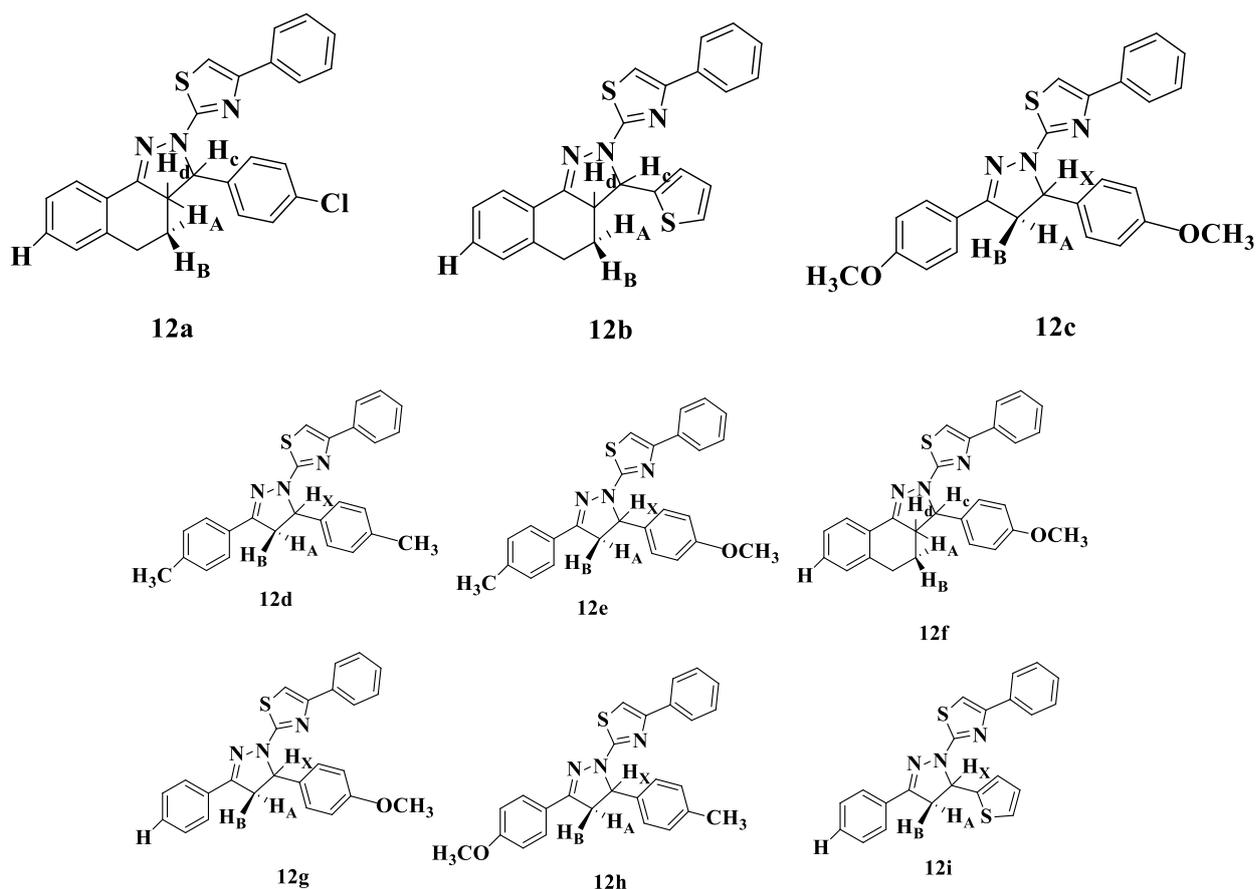
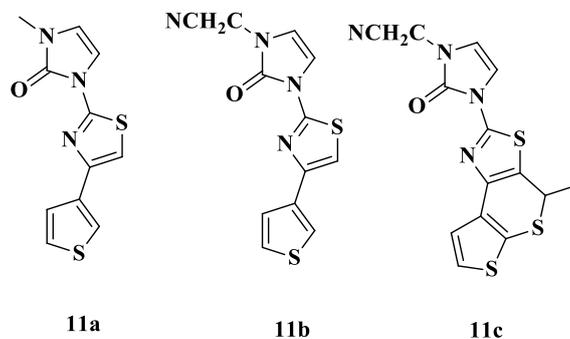


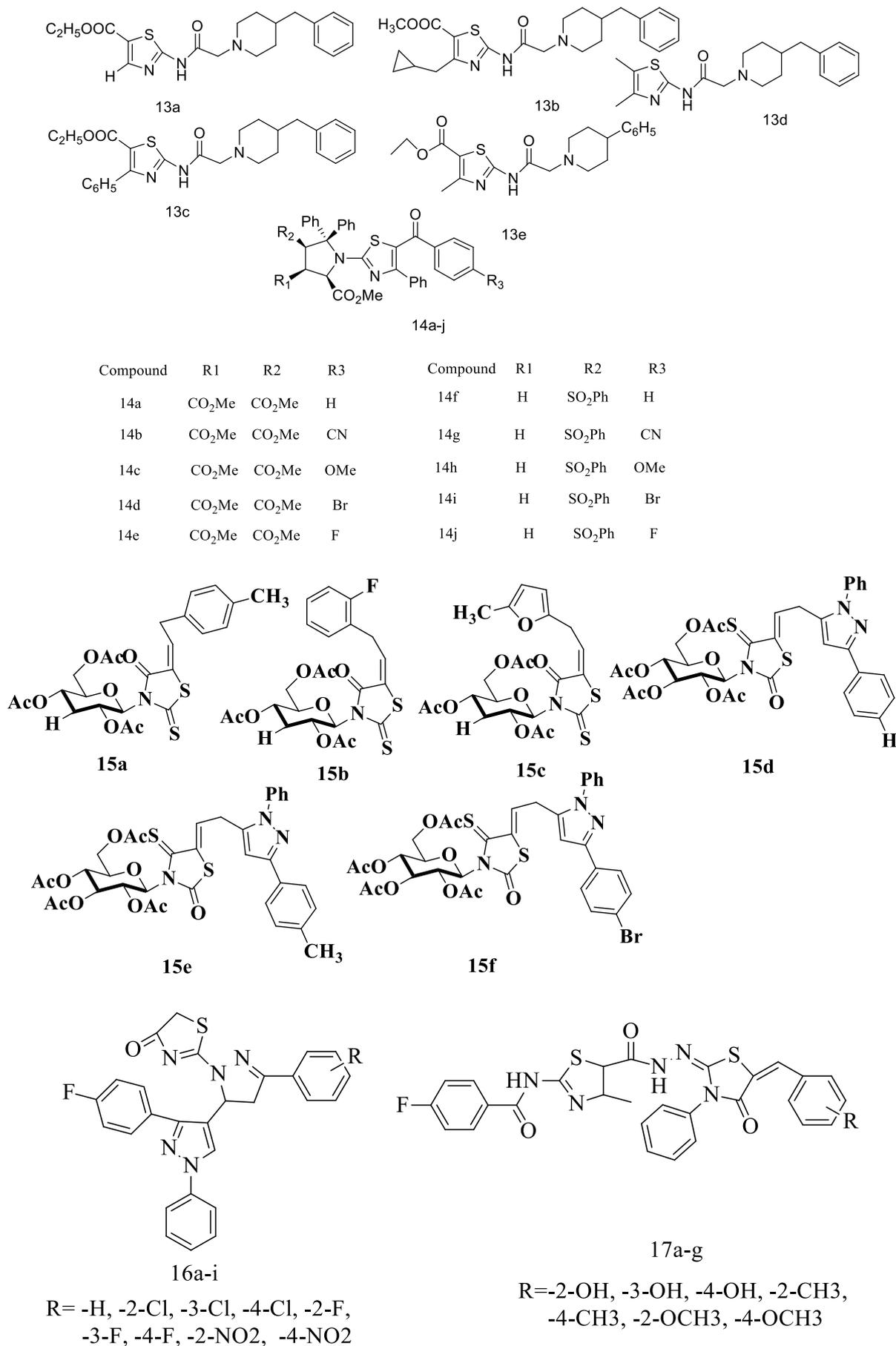
**Figure 1.** Various antibiotics having an active thiazole nucleus.

## 2. Results and Discussions

Thiazole and its derivatives show potent antimicrobial activity against various bacteria and pathogens. In this regard, Bobade *et al.* reported a series of thiazole derivatives and examined their antibacterial activity against various bacteria (Figure 2). The microbial study found that 11a-11c ascribe excellent and prominent antibacterial activity against the fungus bacteria [32]. A series of novel 2-(3,5-diphenyl-4,5-dihydro-1H-pyrazol-1-yl)-4-phenylthiazoles (12a-i) was demonstrated by Sharifzadeh *et al.* and investigated the antibacterial activity against gram-positive and negative bacteria. From the antibacterial data, it is found that 12a-d showed moderate activity against *Escherichia coli*. However, 12e-i showed moderate activity against *Staphylococcus Aureus* bacteria [33]. A series of acetamide substituted thiazole derivatives (13a-e) was reported by Pawar *et al.* All the derivatives displayed potent microbial activity against *Escherichia coli*, *Staphylococcus aureus*, and *Bacillus subtilis* by using the broth dilution method [34]. Nural *et al.* reported a series of methyl 5,5-diphenyl-1-(thiazol-2-yl)pyrrolidine-2-carboxylate derivatives (14a-j) and studied their biological activity against different bacterial and fungal strains and *M. tuberculosis* H37Rv strain. The authors found that 14a-j exhibited persuasive antibacterial activity as compared to the reference drug molecules [35]. A bunch of 2,3,4,6-tetra-O-acetyl- $\alpha$ -D-glucopyranosyl derivatives (15a-f) was reported by Metwali *et al.* The antibacterial activities were demonstrated against various bacteria. The microbial study confirmed that all the compounds exhibited considerable inhabitation against *Escherichia coli* and *Staphylococcus aureus* bacteria using the agar dilution method [36]. Pyrazole-based thiazole derivatives play an important role in the pharmaceutical field. In this context, a series of thiazole derivatives (16a-i) reported by Desai *et al.* The authors suggested that 16a-i displayed potent activity against

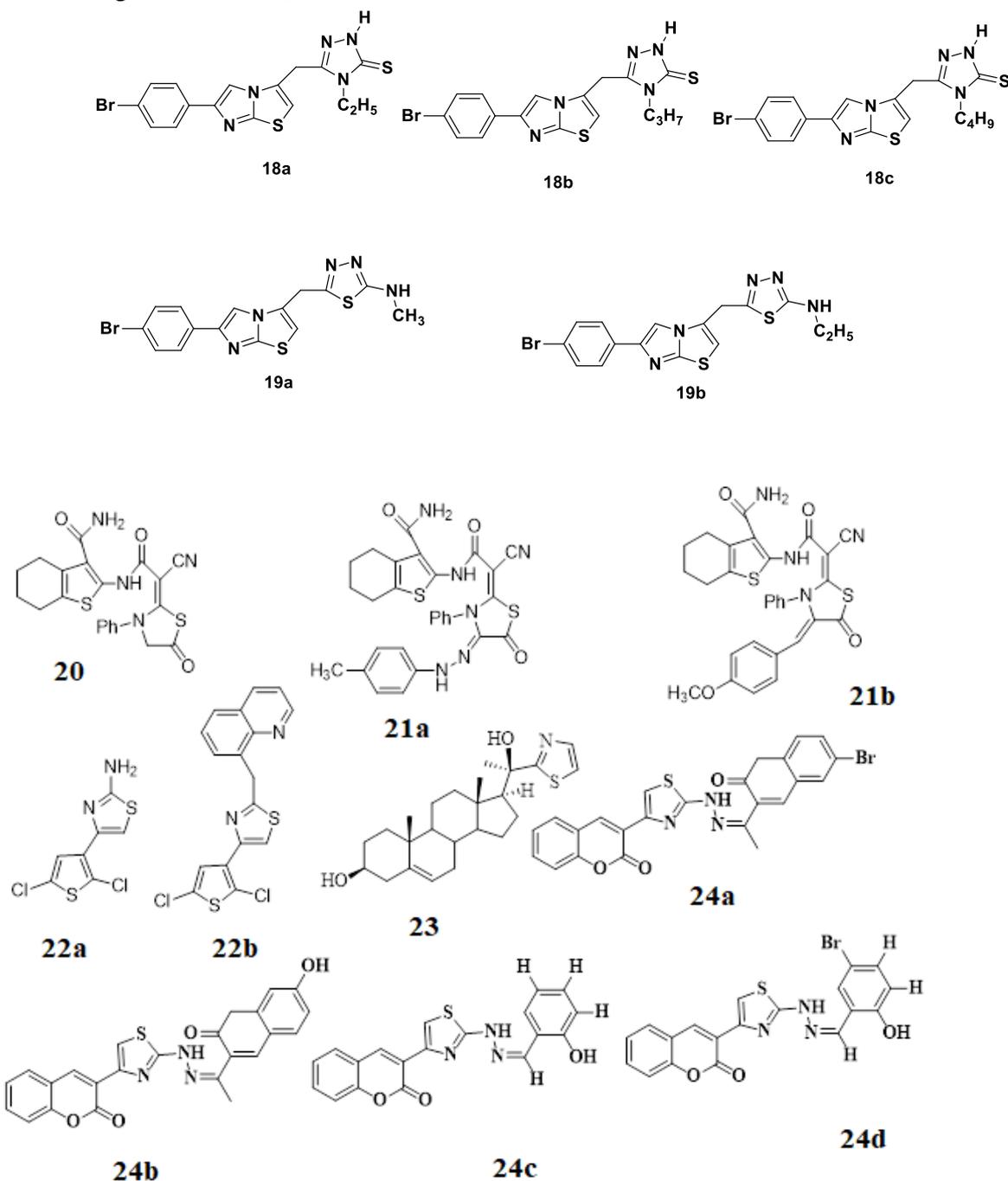
various bacteria compared to that of reference drug Ampicillin. The presence of an electron-withdrawing group on the benzene ring enhanced the antibacterial activities of these derivatives [37]. Similarly, derivatives (17a-g) were employed to detect the antibacterial activity against gram-positive and negative bacteria using the broth dilution method. From the experimental data, it is found that all the synthesized derivatives show prominent antibacterial activity against *Staphylococcus aureus*, *Staphylococcus pyogenic*, *Escherichia coli*, and *Pseudomonas aeruginosa* [38].

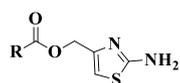




**Figure 2.** Various thiazole derivatives with antibacterial activities against various bacteria.

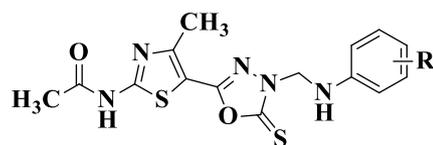
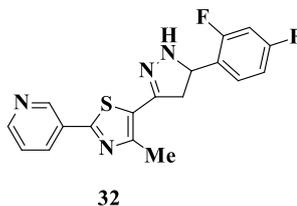
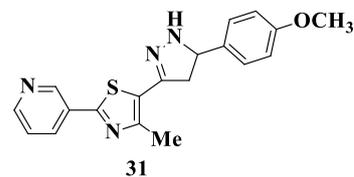
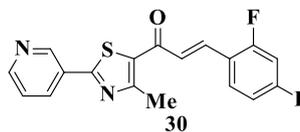
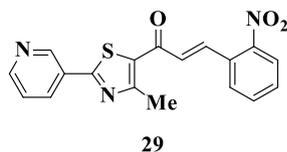
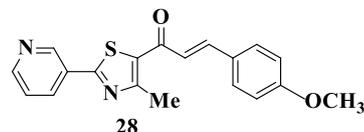
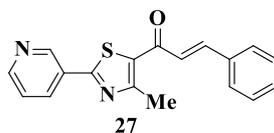
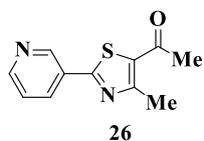
The antibacterial activities of 1,2,4-triazoles and 1,3,4-thiadiazoles bearing imidazole[2,1-b]thiazole derivatives (18-19) were screened against various pathogen and bacteria by using the micro broth dilution method. It revealed that all the derivatives have potent antibacterial activity against *S. aureus*, *E. coli*, *T. tonsurans*, and *T. mentagrophytes* var [39]. Gouda *et al.* reported a series of thiazole and pyrazole derivatives (20-21) and examined the antibacterial activity against various bacteria. All the synthesized derivatives showed better antibacterial activity than the reference drug molecules [40]. The thiazole derivatives (22a-b) were used for the antibacterial activity against gram-positive and negative bacteria using the disc diffusion method. The authors suggested that 22a-b show better activity as compare to reference drug molecule [41].



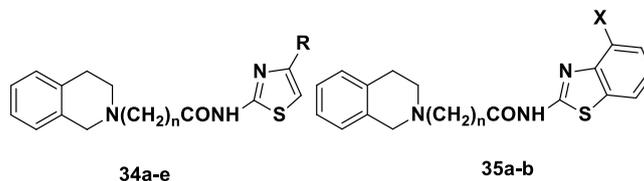


(25a-t)

Compound	(Molecular formula)	Compound	(Molecular formula)
25a	C <sub>14</sub> H <sub>13</sub> ClN <sub>2</sub> O <sub>2</sub> S	25j	C <sub>11</sub> H <sub>8</sub> ClFN <sub>2</sub> O <sub>2</sub> S
25b	C <sub>13</sub> H <sub>11</sub> F <sub>3</sub> N <sub>2</sub> O <sub>2</sub> S	25k	C <sub>11</sub> H <sub>7</sub> F <sub>3</sub> N <sub>2</sub> O <sub>2</sub> S
25c	C <sub>13</sub> H <sub>11</sub> F <sub>3</sub> N <sub>2</sub> O <sub>3</sub> S	25l	C <sub>9</sub> H <sub>8</sub> N <sub>2</sub> O <sub>3</sub> S
25d	C <sub>12</sub> H <sub>8</sub> F <sub>4</sub> N <sub>2</sub> O <sub>2</sub> S	25m	C <sub>15</sub> H <sub>12</sub> N <sub>2</sub> O <sub>2</sub> S
25e	C <sub>14</sub> H <sub>13</sub> N <sub>3</sub> O <sub>2</sub> S	25n	C <sub>11</sub> H <sub>9</sub> N <sub>2</sub> O <sub>2</sub> S
25f	C <sub>12</sub> H <sub>9</sub> N <sub>3</sub> O <sub>2</sub> S	25o	C <sub>11</sub> H <sub>7</sub> Cl <sub>3</sub> N <sub>2</sub> O <sub>2</sub> S
25g	C <sub>9</sub> H <sub>8</sub> N <sub>2</sub> O <sub>2</sub> S <sub>2</sub>	25p	C <sub>11</sub> H <sub>10</sub> N <sub>2</sub> O <sub>2</sub> S
25h	C <sub>11</sub> H <sub>8</sub> ClN <sub>3</sub> O <sub>4</sub> S	25s	C <sub>11</sub> H <sub>9</sub> BrN <sub>2</sub> O <sub>2</sub> S
25i	C <sub>11</sub> H <sub>8</sub> N <sub>4</sub> O <sub>2</sub> S	25t	C <sub>11</sub> H <sub>9</sub> N <sub>3</sub> O <sub>4</sub> S

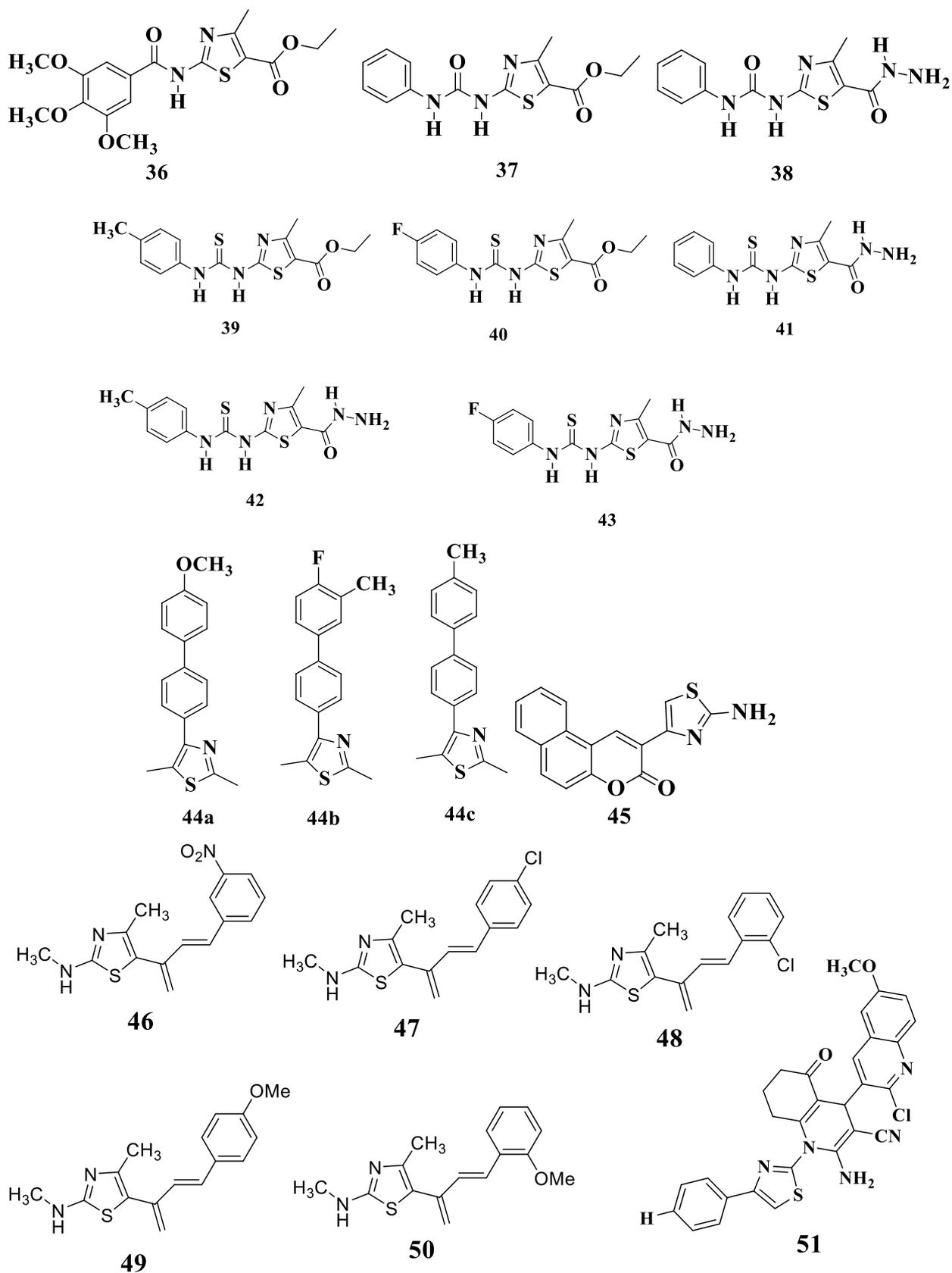


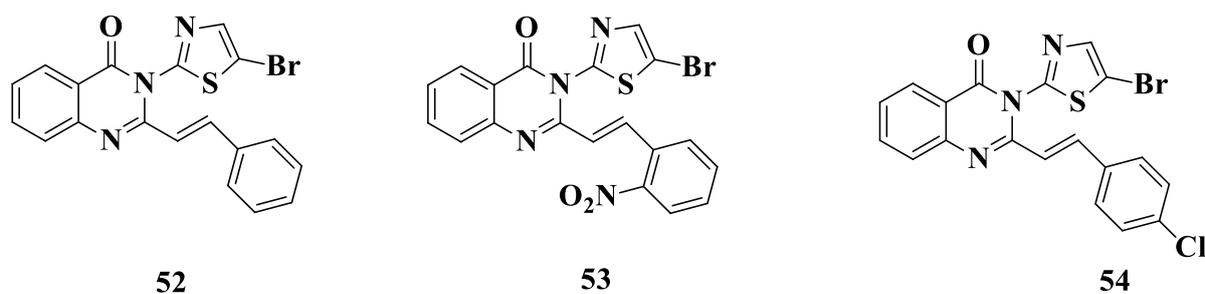
R=-33a-F, -33b-F, -33c-OCH<sub>3</sub>, -33d-NO<sub>2</sub>, -33e-NO<sub>2</sub>



34a R=H n=1  
 34b R=CH<sub>3</sub> n=1  
 34c R=p-CH<sub>3</sub>OC<sub>6</sub>H<sub>4</sub> n=1  
 34d R=H n=2  
 34e R=p-CH<sub>3</sub>OC<sub>6</sub>H<sub>4</sub> n=2

35a X=H n=1  
 35b X=Cl n=1



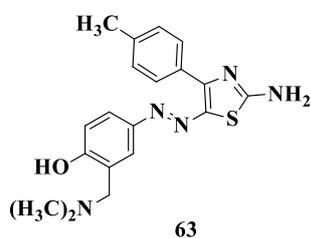
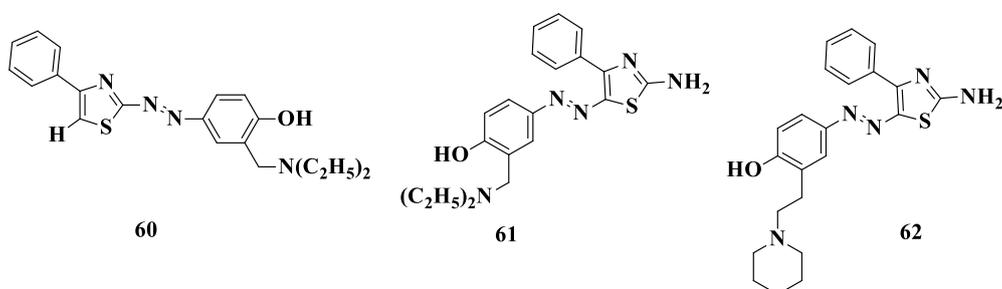
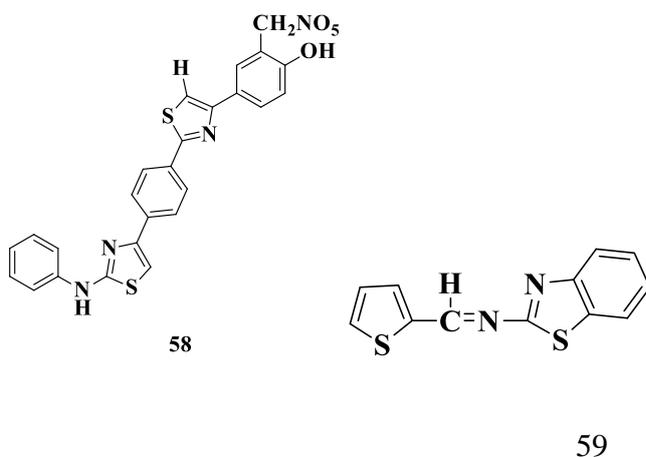
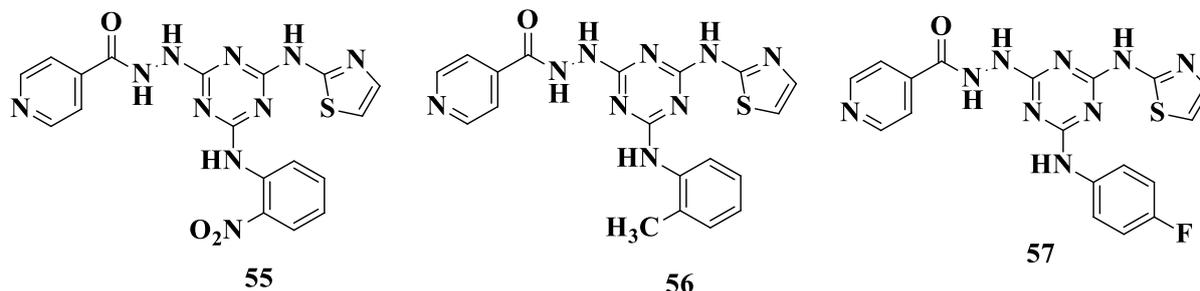


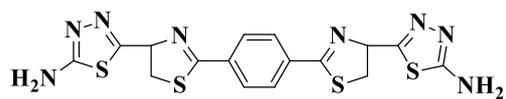
**Figure 3.** Various thiazole derivatives used for antibacterial studies.

The derivative (23) was used to detect antibacterial activity against various bacteria. Amphotericin B and Fluconazole were used as standard drug molecules. From the antibacterial analysis data, it was found that 23 has excellent activity against various bacteria compared to the reference drug [42]. Arshad *et al.* reported a series of novel coumarin-based derivatives (24a-d) and examined the antibacterial activity against various bacteria using a broth dilution method. All the derivatives showed significant antibacterial activity against *Staphylococcus aureus* and *Haemophilus influenza* [43]. A series of new (2-aminothiazol-4-yl) methyl ester derivatives (25a-t) and demonstrated the antibacterial activity against various bacteria. All the synthesized derivatives showed prominent antibacterial activities as compared to the reference drug [44].

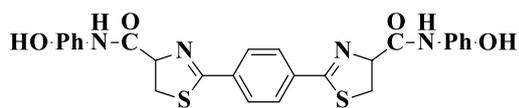
2-(3-pyridyl)-4,5-disubstituted thiazole derivatives (26-32) were used to study the antibacterial activity against various pathogens. All the derivatives showed prominent antibacterial activity as compared to the reference drug. It occurred due to the presence of both electron-withdrawing and donating groups [45]. A bunch of 1,3,4-oxadiazoles based thiazole derivatives (33a-e) was designed and ascribed the antibacterial activity by using the broth microdilution technique. All the derivatives showed superior activity as chloramphenicol, which acts as a reference drug molecule [46]. Jablotskaya *et al.* reported a series of compounds (34-35) and investigated the antibacterial activity against various bacteria using the agar-dish diffusion method. All the derivatives show excellent antibacterial activity compared to the reference drug molecules such as fluconazole and gentamicin [47]. Similarly, a series of thiazole derivatives (36-43) was reported by Rostom *et al.* and examined the antibacterial activity against various bacteria and pathogen through the agar diffusion method. Gentamicin and ampicillin trihydrate used as reference drug molecules. The authors found that all the derivatives show better antibacterial activity as compared to the reference drug molecule [48]. The antibacterial activities of a few novel thiazole derivatives (44a-c) were reported by Reddy *et al.* against various gram-positive and negative bacteria. It is observed that 44c has higher activity than 44a-b [49]. Coumarin-based thiazole derivative (45) was reported by El-Wahab *et al.* and investigated the biological activity against various bacteria using the paper disk diffusion technique. From the experimental data, it is observed that 45 shows significant antibacterial activity. The presence of coumarin moiety enhanced the antibacterial properties [50]. Based on the basic requirement of the effective antibacterial drug, Liaras *et al.* reported chalcone-based thiazole derivatives (46-50) and executed the biological activity using the microdilution method. It is observed that 46-50 showed potent activity against *S. typhimurium*, *E.coli*, *M. flavus*, and *B. cereus* [51]. Shah *et al.* designed and synthesized a novel thiazole derivative (51) and examined the antibacterial activity against various bacteria. The result revealed that 51 shows effective antibacterial activity against various bacteria [52]. Similarly,

the novel thiazole derivatives (52-54) were used to detect the antibacterial activity against various pathogens using the cup-plate agar diffusion method. The experimental results found that all the derivatives showed potent activity against *P. aeruginosa*, *B. subtilis* bacteria [53].

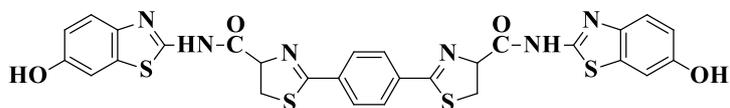




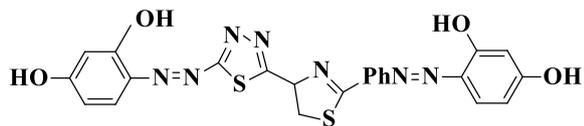
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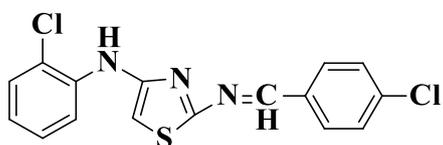
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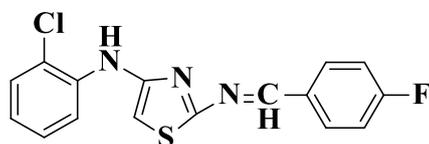
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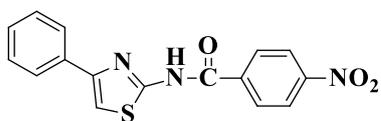
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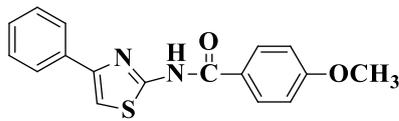
68a



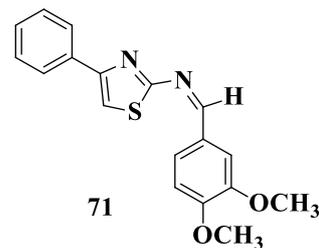
68b



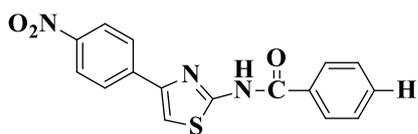
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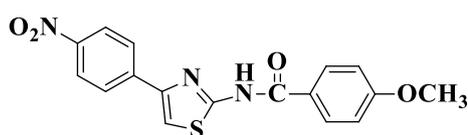
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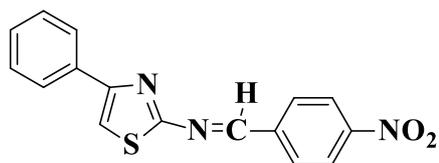
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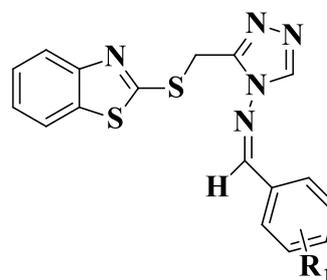
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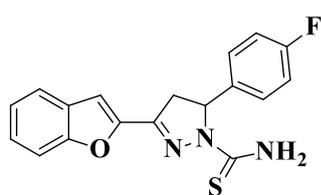


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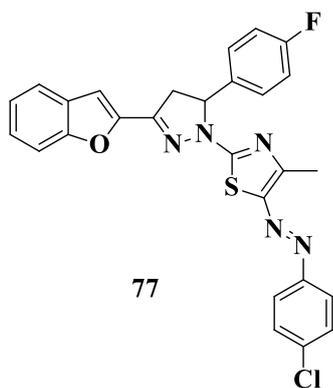


(75a-d)

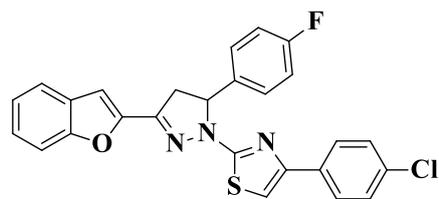
75a=-H,b=-4NO<sub>2</sub>,c=-2Cl,d=-2OH



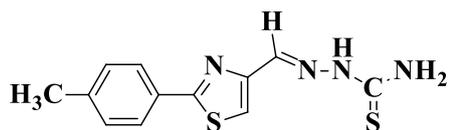
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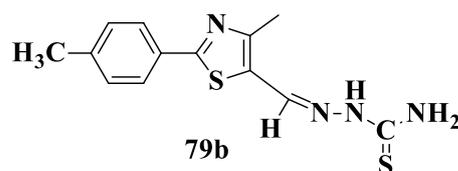
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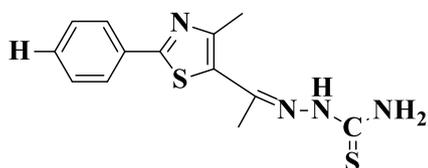
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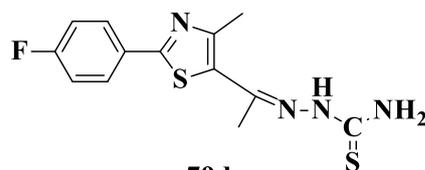
79a



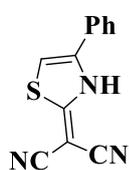
79b



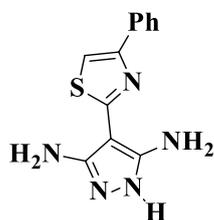
79c



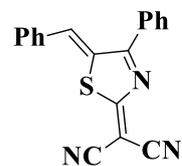
79d



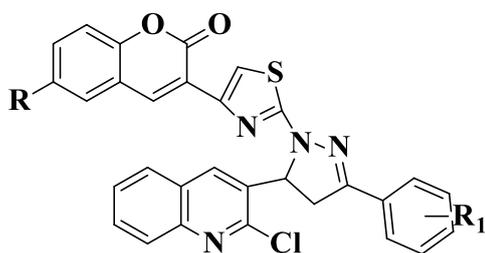
80a



80b

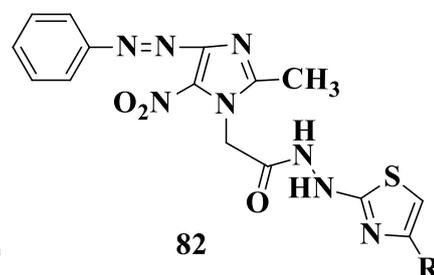


80c



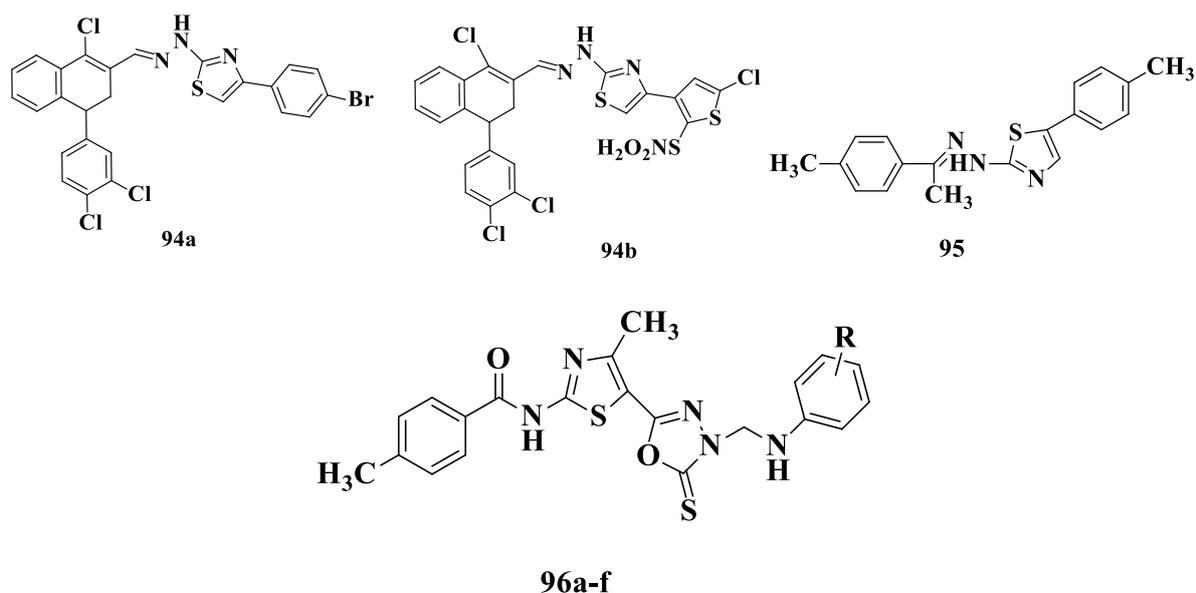
81a-c

81a) R=F, R1=2-F; b) R=F, R1=3-F; c) R=F, R1=4-F



82



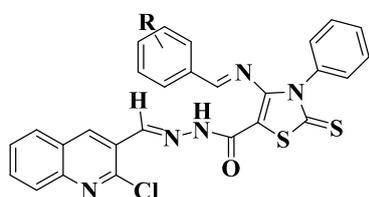


a; -2-F, b; -3-F, c;-4-F, d;-2-NO<sub>2</sub>, e; -3-NO<sub>2</sub> f;-4-NO<sub>2</sub>

**Figure 4.** Various thiazole derivatives used for antibacterial studies.

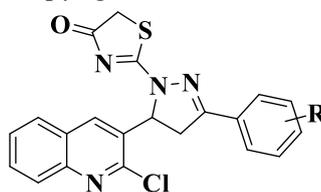
Desai *et al.* reported a bunch of 1,3,5-triazine based triazole derivatives (55-57) and envisaged the biological activity against various pathogens by using the Mueller Minton broth dilution method. All the derivatives showed potent activity against *E. coli*, *S. aureus*, *P. aeruginosa*, and *S. pyogenes* [54]. The biological activities of 2-phenylamino-thiazole derivative (58) displayed by using the Mueller Hinton broth dilution method against various pathogens. It revealed that 58 has excellent biological activity against *C. albicans* and *C. krusei* like bacteria [55]. It is well known that Schiff bases have numerous biological activities such as antibacterial, antifungal and antitumor, and so on. In this regard, Etaiw *et al.* reported 2-aminobenzothiazole derivative (59) and 59-M complexes (M = Ni(II), Cu(II), and Zn(II)). The experimental results show that the complexes (59-M) show better antibacterial activity than 59 by using the agar diffusion technique [56]. A series of thiazole derivatives (60-63) were used for biological activity using the agar dilution method against various bacteria. All the derivatives showed excellent antibacterial activity against gram-positive and negative bacteria. The authors reported that all the derivatives showed potent activity compared to the reference drug molecule [57]. The novel thiazole derivatives (64-67) showed prominent antibacterial activity against various bacteria and pathogens using the agar diffusion method [58]. Schiff base derivatives (68a-b) exhibited potent antibacterial activity against *B. subtilis*, *S. aureus*, *K. pneumoniae*, and *E. coli* by using the paper disc technique [59]. The novel thiazole derivatives (69-73) were employed for antibacterial activity against various pathogens using the tube dilution technique. The authors reported that 69, 72, and 73 exhibited potent antibacterial activity than 70 and 71. It is due to the presence of electrons withdrawing (-NO<sub>2</sub>) groups [60]. The derivative (74) showed antibacterial activity against *B. cereus* bacteria by using the agar process. The antibacterial property of 94 is better than the reference drug ampicillin [61]. The derivatives (75a-d) envisaged prominent activity against *B. subtilis*, *E. coli*, *K. pneumoniae*, and *P. aeruginosa* bacteria by using nutrient agar medium [62]. To make more targeted antibacterial drug agent, the antibacterial activities of a few fluorinated-2(3-(benzofuran-2-yl)pyrazol-1-yl)thiazole derivatives (76-78) were evaluated against *B. subtilis* and *S. aureus*.

Ciprofloxacin is used as a reference drug molecule. The result showed that 76-78 have energetic antibacterial activity against various bacteria compared to reference drugs. [63]. Similarly, the derivatives (79a-d) exhibited potent antibacterial activity against *E. coli* and *B. subtilis* using the well-plate technique [64]. The thiazole derivatives (80a-c) showed better antibacterial activity than the references drug cefuroxime and nitrofurantoin [65]. A series of novel 3-(2-(5-(2-chloroquinoline-3-yl)-3-substituted phenyl-4,5-dihydro-1H-pyrazol-1-yl)thiazol-4-yl)-6-H/halo-2H-chromen-2-ones derivatives (81a-c) was reported by Ansari *et al.* The antibacterial activity was examined by using serial plate dilution technique. All the derivatives exhibited powerful antimicrobial activity against *E. coli* and *S. aureus* [66]. The derivatives (82a-b) envisaged better antibacterial activity against various pathogens by using the cup-plate method [67]. The derivatives (83-85) exhibited potent antibacterial activity against *C. albicans*, *B. cereus*, and *L. monocytogenes* bacteria by using the cup-plate agar diffusion method [68]. Asundaria *et al.* reported a series of novel thiazole derivatives (86-87). The derivatives showed prominent activities against various pathogens [69]. The derivatives (88-93) ascribed potent antibacterial activity against various pathogens by using the agar diffusion method [70]. Chidananda *et al.* reported a novel thiazole derivative (94a-b) and examined their biological activity against various bacteria by using the disc diffusion technique. The authors confirmed that 94a-b have effective biological activity against *P. aeruginosa* and *E. coli* like bacteria [71]. The derivative (95) displayed moderate antibacterial activity against various pathogens using the agar plate technique [72]. Many novel 1,3,4-oxadiazoles based thiazole derivatives (96a-f) were designed and envisaged antibacterial properties by using the broth dilution method. The derivatives ascribed potent activities against *S. pyogenes* and *P. aeruginosa* like bacteria [73].



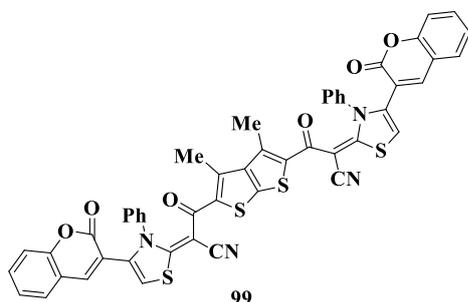
97a-b

a; R = 2-OH, b; R = 4-OH

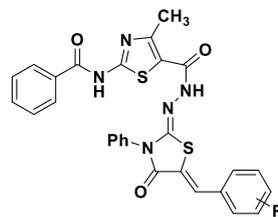


(98a-e)

R; a; =2-Cl, b; =2-F, c; =3-F, d; = 4-F, e; = 4-NO<sub>2</sub>

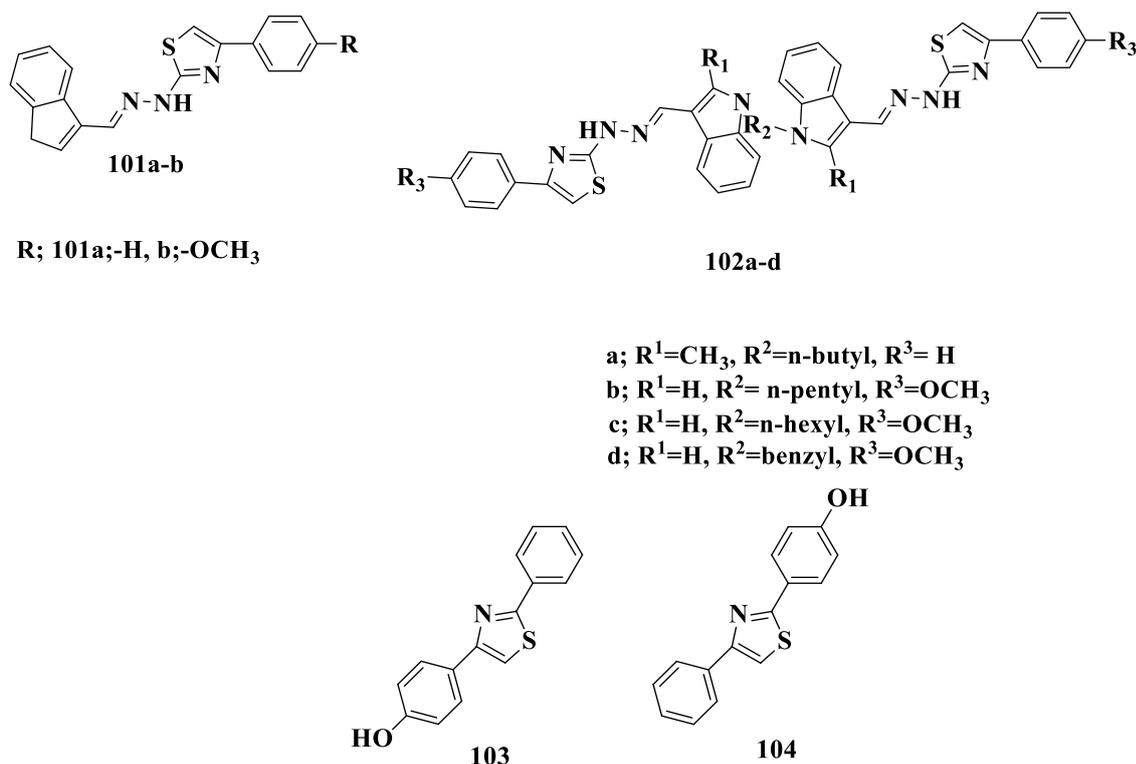


99



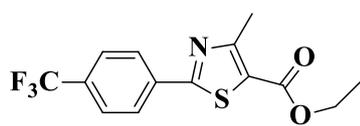
(100a-f)

R; a; =-2-OH, b; =-4-OH, c; =-2-CH<sub>3</sub>, d; =-4-CH<sub>3</sub>, e; =-2-OCH<sub>3</sub>, f; = -4-OCH<sub>3</sub>

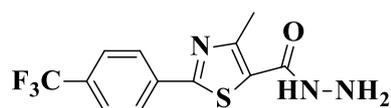


**Figure 5.** Various thiazole derivatives used for antibacterial studies.

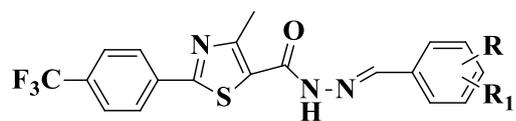
Due to the enhancement of the mortality rate, it is required to discover new antibacterial drugs with a novel mode of action towards bacteria pathogen without any side effect. In this regard, Desai *et al.* designed some novel quinolone-thiazole derivatives (97a-b) and performed their antibacterial screening by using a broth dilution technique. The antimicrobial screening data showed that 97a-b have potent biological significance towards *S.aureus*, *E.coli*, *S.pyogenes*, and *P.aeruginosa* [74]. Desai *et al.* reported a bunch of active thiazole derivatives (98a-d) having a quinolone-pyrazoline backbone and examined their biological activity against various bacteria pathogens. It has been found from the antimicrobial screening data that all the derivatives have considerable antibacterial activity against various gram bacteria. Ampicillin and griseofulvin were used as reference molecules [75]. The thiophene-based thiazole derivative (99) shows moderate antibacterial activity against various pathogens. Streptomycin and Penicillin were used as reference molecules [76]. To effectively treat bacterial disease caused by infectious bacteria, it is very important to develop an effective antibacterial drug with great accuracy. On that aspect of research, Desai *et al.* synthesized some novel thiazole and thiazolidine derivatives (100a-f) and analyzed their biological characteristic by using broth dilution techniques against infectious bacteria. The result was that 100a-f has strong antibacterial activity due to electron-donating groups [77]. Indole and its derivative have significant biological activities like antibacterial, antifungal, anticancer, etc. So, the addition of indole moieties with biologically active heterocyclic thiazole derivative creates hope of producing a potent antibacterial drug to reduce the bacterial mortality rate. Mahmoodi *et al.* synthesized a series of derivatives (101-102) and examined their antibacterial activity against *P.aeruginosa* and *B.subtilis*. The authors reported that all the derivatives showed prominent biological activity against the various bacteria [78]. The compounds (103-104) have powerful biological activity against various gram bacteria by using the agar diffusion technique [79].



105

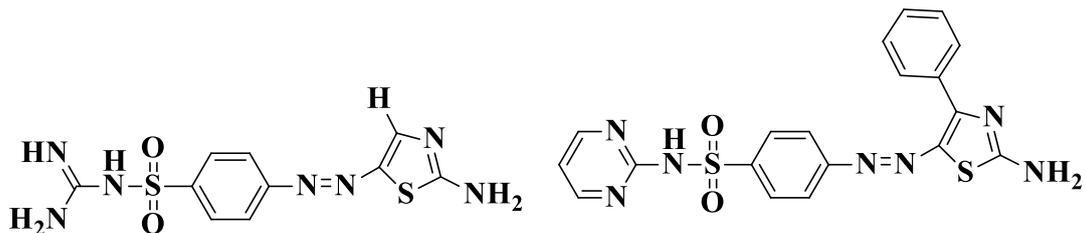


106



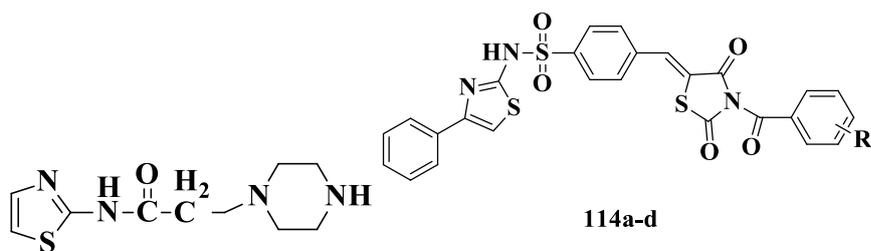
(107-111)

R/R<sub>1</sub>; 107)=H/4-Br, 108)=H/4-F, 109)=H/4-OH, 110)=2-Cl/4-Cl, 111)=2-Cl/6-Cl.



112a

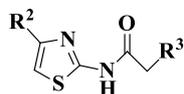
112b



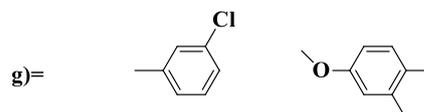
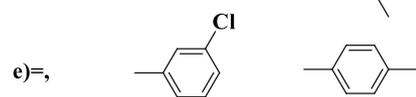
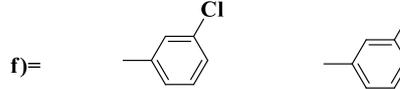
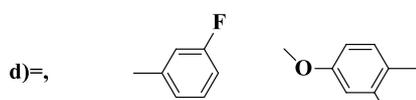
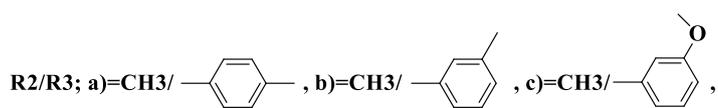
114a-d

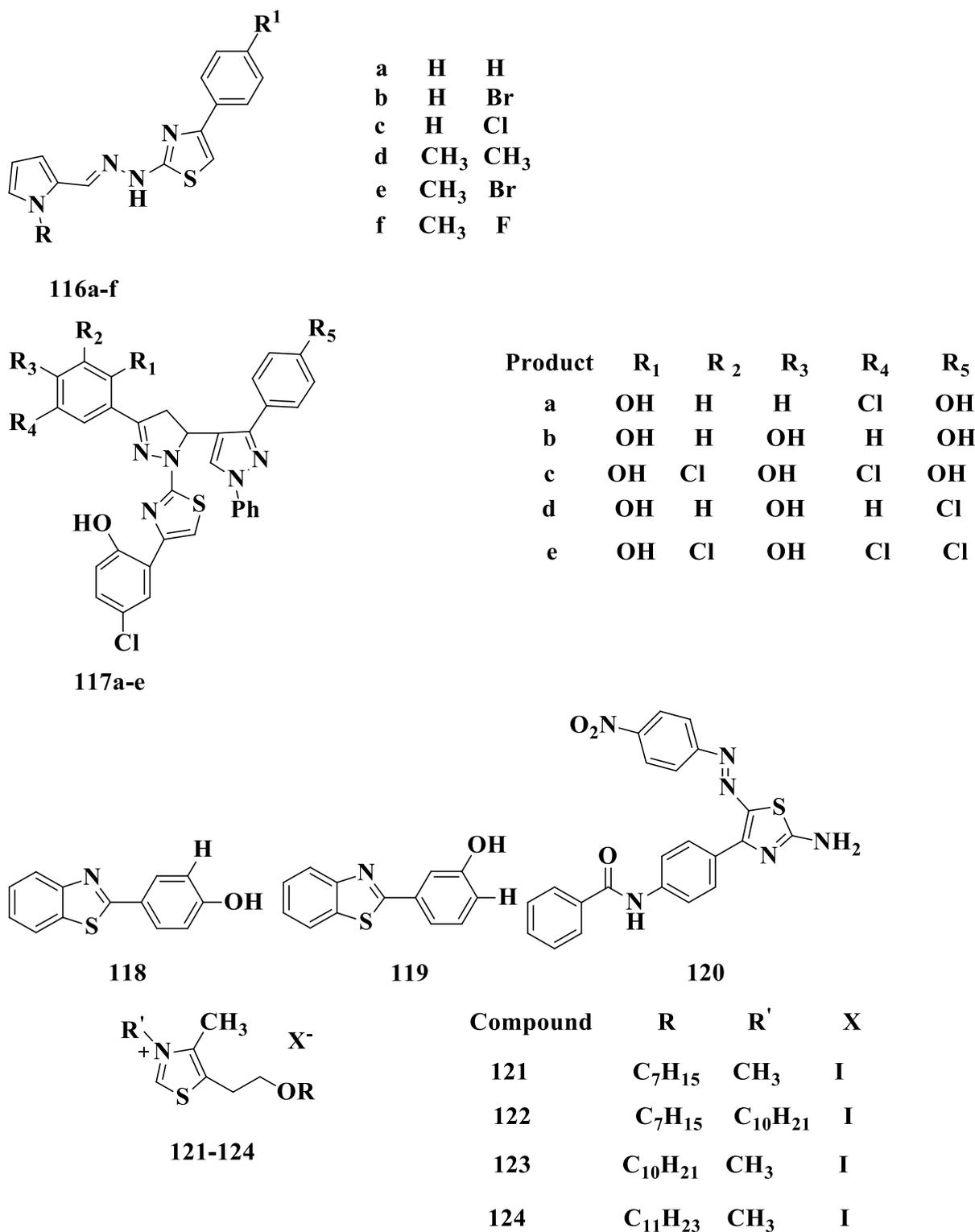
113

R; a)=4-CH<sub>3</sub>, b)=2-Cl, c)=4-Cl. d)=2,4-NO<sub>2</sub>



115a-g





**Figure 6.** Various thiazole derivatives used for antibacterial studies.

Nastasa *et al.* depicted the synthesis of new hydrazone bearing thiazole derivatives (105-111) and performed their antibacterial properties using the agar diffusion technique. The result showed that the compounds 105-111 have potent biological activity against *S.aureus* and *E.coli* like bacteria [80]. From the literature, it is well documented that azo dyes have active biological activities like antibacterial, antifungal, etc. Gaffer *et al.* reported a series of aryl azothiazole derivatives (112a-b) and examined their biological activity by using the agar diffusion method. The antimicrobial analysis data confirmed that the derivatives 112a-b have

a formidable antibacterial response towards various gram-positive bacteria [81]. By using the cup-plate agar diffusion method, the authors found that 113 has considerable antibacterial activity against various gram-positive bacteria [82]. Thiazole and thiazolidinone derivatives of thiazolidine have a strong antimicrobial impact. Parekh *et al.* reported a few derivatives (114a-d) and examined their antimicrobial screening properties by using the microdilution method. From the experimental data, it is observed that 114a-d have incredible antibacterial activity towards *B.subtilis* and *S.aureus* like bacteria [83]. By using the disc diffusion technique, it is observed that 115a-g have profound biological activity against *K.pneumonia*, *E.coli*, *S.aureus*, and *P.aeruginosa* like bacteria [84]. Yurttas *et al.* discovered a series of new hydrazone bridged thiazole-pyrrole derivatives (116a-f) and examined their antimicrobial activity using the broth dilution method. The biological analysis data found that nearly all the compounds show potent antimicrobial activity towards various bacteria [85]. By using the nutrient agar plate seeded technique, it is found that 117a-e has potent antibacterial activity against *E.coli* and *P.vulgaris* like bacteria due to electron-rich nitrogen heterocycles [86]. The authors found that 1,3-thiazole derivatives (118-119) have potent biological activity against various gram-positive and negative bacteria using the clay-pot process [87]. The derivative (120) displayed potent antibacterial activity towards *Bacillus licheniformis*, *Enterobacter cloacae*, and *E.coli*-like bacteria due to incorporating the 4-NO<sub>2</sub> group [88]. By using the agar-dish diffusion method, it is found that 121-124 have strong inhibition against gram-positive bacteria [89].

### 3. Conclusions and Future Prospects

The development of efficient and targeted drugs is a demandable interest for medicinal chemists. Thiazole derivative drugs have achieved a triumphant place in the pharmacological research field because of their utilization as therapeutic agents to control various bacterial disorders. A number of thiazole derivatives are in clinical trials and may be used as an active antibacterial agent in the future. This review provides a magnificent understanding of thiazole derivatives in the field of bacterial therapy against different bacteria. Data collected from the numerous reported articles conclude that those thiazole derivatives have excellent heterocyclic scaffolds with enormous antibacterial activity. This review is also signifying that the potential of the thiazole nucleus for the improvement of new drug therapy of bacterial diseases and disorder become increasing day to day as various patent has been filed based on thiazole derivative. This review will provide a suitable path for the scheming of thiazole-based antibacterial active agents. Hence, this review will contribute insight into the design and development of novel and selective thiazole derivatives based on their recent trends in bacterial diseases.

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## Conflicts of Interest

The authors have declared that no competing interests exist.

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