Schiff bases are organic compounds that contain imine or azomethine (C=NR) group and are often produced from condensation of aldehydes or ketones with primary aliphatic/aromatic amines. Quinoline Schiff bases are formed if either or both of the reaction participants possess quinoline ring. Quinoline nucleus is an essential part of the chemical structure of natural products, and pharmaceutical and biologically active compounds. Quinoline Yellow WS is a water-soluble greenish yellow food additive which is derived from the dye Quinoline Yellow SS (1). Bosutinib as a tyrosine kinase agonist is prescribed to treat Philadelphia chromosome-positive leukemia (2). Furthermore, Apomorphine as a morphine derivative, dopamine D2 inhibitor, and emetic agent has been used in the treatment of acute poisoning and parkinsonism (3). Mefloquine is an effective antimalaria drug against Plasmodium falciparum parasite (4). Imiquimod acts as an immune response modifier and helps to treat genital and anal warts, actinic keratoses, and superficial basal cell carcinoma (5). Cinchocaine or dibucaine is a surface anesthetic with high toxicity that has been restricted to spinal anesthesia (6).

Schiff bases are suitable multidentate ligands for metal complexation. The therapeutic potential of both coordinated and uncoordinated forms has been proven against pathogenic bacteria (7), fungi (8), viruses (9), protozoa (10), and helminths (11). In addition, quinolones are highly bioavailable antibiotics with a diverse range of activities and functions that are used to treat respiratory and urinary tract infections. The antibiotic examples of current quinolones and fluoroquinolones are as follows: moxifloxacin, lomefloxacin, gatifloxacin, norfloxacin, ofloxacin, nalidixic acid, rosoxacin, and ciprofloxacin. Mallandur et al synthesized some quinoline- and benzimidazole-based Schiff bases; their antibacterial effects were assessed against Escherichia coli, Staphylococcus aureus, and Salmonella typhi via disc diffusion and broth microdilution.
broth microdilution methods (12). Schiff bases of 2,6-disubstituted quinoline-3-carbaldehyde and their zinc and copper complexes were synthesized by Mandewale et al as potential aurora kinase (essential serine/threonine kinases for cell proliferation) inhibitors (13). Antimicrobial activities of 2-sulfanyl or 2-hydroxyquinoline-3-carbaldehyde Schiff bases and their corresponding copper (II), cobalt (II), zinc (II), and nickel (II) complexes were evaluated on *E. coli* and *S. aureus* by zone of inhibition method (14). The inhibitory activities of two Schiff bases derived from 2-chloroquinoline-3-carbaldehyde were also investigated on *Bacillus cereus*, *S. aureus*, *Pseudomonas aeruginosa*, and *E. coli* (15).

Other methods were proposed to synthesize imines besides the reaction of aldehydes/ketones and amines. The acid-catalyzed interaction of hydrazoic acid with tertiary alcohols to afford imines is referred to as the Schmidt reaction (16). The *in situ* oxidation of primary alcohols to corresponding aldehydes catalyzed by *N*-heterocyclic carbene (NHC)-silver (I) complexes (17), manganese dioxide (18), palladium (19), *ortho*-naphthoquinone (20), and ferric nitrate (21) has produced imines in good yields. The retro-aza-Henry-type reaction of amines with nitrostyrenes (22), intermolecular alkyne hydroamination (23), Pd-catalyzed reaction of aryl halides, and bulky arylamines (24) were also developed for this purpose.

In order to expand potential antimicrobial agents, the inhibitory activity of some synthesized Schiff bases of 2-chloro-3-quinolinecarboxaldehyde was evaluated against the pathogenic genera *Rhodococcus*, *Streptococcus*, *Staphylococcus*, *Enterococcus*, *Bacillus*, *Shigella*, and *Proteus*.

**Subjects and Methods**

**Chemicals**

All reagents were prepared from reputable chemical companies. The uncorrected melting points were determined by Kruss KSP1N melting point apparatus. Aluminum TLC plates (20×20 cm) containing silica gel coated with fluorescent indicator F254 were used to monitor the progress of reactions. Bruker Tensor-27 FT-IR spectrometer was applied to record the FT-IR spectra of compounds. ¹H and ¹³C NMR spectra were registered using a Bruker 400 MHz-NMR spectrometer.

**Synthesis of 2-chloroquinoline-3-carbaldehyde (2)**

A total of 120 mmol phosphoryl chloride (18.36 g) was gradually added to 10 mmol acetanilide (1, 1.34 g) and 30 mmol dry DMF (2.30 mL) at 0-5°C (21). The solution was warmed to 90°C, and stirred under these conditions for 16 hours. The contents of reaction were cooled to the room temperature, and poured into 100 g crashed ice. The precipitate was filtered and washed with water. The solid was recrystallized from acetonitrile to achieve a yield of 90% (1.97 g) of pure white compound 2.

**General Procedure for the Synthesis of Quinoline Schiff Bases 4a-g**

A solution of 1 mmol aniline derivatives 3a-g in 5 mL ethanol was added dropwise to a solution containing 1 mmol 2-chloroquinoline-3-carbaldehyde (2) at room temperature. The mixture was refluxed for 3-7 hours. The progress of the reaction was checked by TLC, including a mixture of ethyl acetate-hexane (2: 1). Pd-catalyzed reaction of aryl halides, and bulky amines (24) were also designed for this purpose.

In order to expand potential antimicrobial agents, the inhibitory activity of some synthesized Schiff bases of 2-chloro-3-quinolinecarboxaldehyde was evaluated against the pathogenic genera *Rhodococcus*, *Streptococcus*, *Staphylococcus*, *Enterococcus*, *Bacillus*, *Shigella*, and *Proteus*.

**Figure 1.** Selected Examples of Biologically Active Compounds Containing Quinoline Ring.
2H, Ph-H-2′,6′), 7.16-7.11 (m, 3H, Ph-H-3′,4′,5′) ppm; ¹³C NMR (100 MHz, DMSO-d₆) δ: 122.6 (Ph-C-2′,6′), 127.0 (Ph-C-4′), 127.9 (Ar-C-4a), 128.1 (Ar-C-6), 128.3 (Ar-C-8), 129.7 (Ar-C-9), 130.1 (Ph-C-3′,5′), 131.6 (Ar-C-7), 137.4 (Ar-C-4), 147.1 (Ph-C-1′), 148.2 (Ar-C-8a), 149.5 (Ar-C-2), 155.7 (CH=NH) ppm.

(E)-1-(2-Chloroquinolin-3-yl)-N-(4-methoxyphenyl) methanimine (4b)

IR (KBr) v: 2925 (C-H), 1615, 1507, 1405, 1330 (C-N), 1248 (C-O), 1163, 1030, 822, 776, 752, 519 cm⁻¹; ¹³C NMR (100 MHz, DMSO-d₆) δ: 9.14 (s, 1H, Ar-H-4), 8.96 (s, 1H, CH=N), 8.27 (d, J = 7.7 Hz, 1H, Ar-H-5), 8.02 (d, J = 8.4 Hz, 1H, Ar-H-8), 7.91 (m, 1H, Ar-H-7), 7.73 (m, 1H, Ar-H-6), 7.44 (d, J = 8.9 Hz, 2H, Ph-H-2′,6′), 7.05 (d, J = 8.9 Hz, 2H, Ph-H-3′,5′), 3.82 (s, 3H, CH₃) ppm; ¹¹B NMR (100 MHz, DMSO-d₆) δ: 7.56 ppm.

IR (KBr) v: 2935 (C-H), 1614, 1501, 1405, 1330 (C-N), 1248 (C-O), 1163, 1030, 822, 776, 752, 519 cm⁻¹; ¹³C NMR (100 MHz, DMSO-d₆) δ: 9.14 (s, 1H, Ar-H-4), 8.96 (s, 1H, CH=N), 8.27 (d, J = 7.7 Hz, 1H, Ar-H-5), 8.02 (d, J = 8.4 Hz, 1H, Ar-H-8), 7.91 (m, 1H, Ar-H-7), 7.73 (m, 1H, Ar-H-6), 7.44 (d, J = 8.9 Hz, 2H, Ph-H-2′,6′), 7.05 (d, J = 8.9 Hz, 2H, Ph-H-3′,5′), 3.82 (s, 3H, CH₃) ppm; ¹¹B NMR (100 MHz, DMSO-d₆) δ: 7.56 ppm.

Antibacterial Susceptibility Testing

Mueller-Hinton broth (MHB) and Mueller-Hinton agar (MHA) as bacterial growth media were prepared by HiMedia Company. Antibiotic and sterile blank discs (6 mm diameter) were respectively purchased from Sigma-Aldrich and Paltan Teb Companies. Gram-positive strains including Staphylococcus epidermidis (PTCC 1435), Rhodococcus equi (PTCC 1633), Enterococcus faecalis (PTCC 1778), Staphylococcus aureus (PTCC
Bacillus subtilis subsp. spizizenii (PTCC 1023), Streptococcus pneumoniae (PTCC 1240), and gram-negative strains including Shigella flexneri (PTCC 1234) and Proteus vulgaris (PTCC 1079) were purchased from the Persian Type Culture Collection. The 0.5 McFarland standard bacterial suspensions (1.5 × 10⁸ CFU mL⁻¹) were initially prepared in MHB using a UV-2100 RAYLEIGH double beam UV-Vis spectrophotometer. All results are as the average of three independent tests.

### Measurement of Inhibition Zone Diameter

The disk-diffusion method was used for the measurement of inhibition zone diameter (IZD) values according to the CLSI (Clinical and Laboratory Standards Institute) M02-A11 guideline (26). In this respect, 3 colonies of initial suspensions were inoculated on MHA plates (100 mm) by a swab, and 5 sterile blank discs were included on inoculated media. Then, 10 μL of compounds (10240 μg mL⁻¹) and/or antibiotic (17.6 μg mL⁻¹) were moved onto the dedicated discs. They were incubated at 37°C for 18 hours. The IZD values were measured in millimeter using caliper.

### Determining the Minimum Inhibitory Concentration

The broth microdilution method was adopted for the determination of minimum inhibitory concentration (MIC) values according to the following CLSI M07-A9 guideline (26): 20 μL of derivatives were dissolved in Table 1. The Chemical Structure of Quinoline Schiff Bases

| Entry | Product | Ar   | Yield (%) | M. P. (°C) |
|-------|---------|------|-----------|------------|
|       |         |      |           | Found      | Lit. (Ref.) |
| 1     | 4a      | C₆H₅ | 70        | 133-135    | 128-130 (27) |
| 2     | 4b      | 4-CH₃O-C₆H₄ | 95    | 176-178    | 175 (28)    |
| 3     | 4c      | 2-HO-C₆H₄ | 85    | 184-185    | 180 (29)    |
| 4     | 4d      | 4-H₃C-C₆H₄ | 80    | 191-193    | 194 (28)    |
| 5     | 4e      | 3-H₃C-C₆H₄ | 80    | 154-156    | (30)        |
| 6     | 4f      | 4-Cl-C₆H₄ | 65    | 199-201    | 204 (28)    |
| 9     | 4g      | 4-HO-C₆H₄ | 95    | 158-160    | -           |
DMSO (20480, 10240, 5120, 2560, 1280, 640, 320, 160 μg mL\(^{-1}\)) or aqueous solution of antibiotic (80, 40, 20, 10, 5, 2.5, 1.25, 0.63), and 80 μL of MHB medium and 100 μL of bacterial suspensions diluted 300 times (5 × 10\(^5\) CFU mL\(^{-1}\)) were added to all wells of an eight-row, 96-well, round-bottom microplate. They were incubated for 20 hours at 37°C with a shaking speed of 100 rpm. The MIC value was determined as the lowest concentration of derivatives or antibiotic without any visible bacterial growth.

### Table 2. Optimization of the Model Reaction Conditions for the Preparation of Schiff Base 4a

| Entry | Solvent     | Time (h) | Yield (%) |
|-------|-------------|----------|-----------|
| 1     | MeOH        | 5        | 40        |
| 2     | EtOH        | 5        | 70        |
| 3     | CH\(_3\)CN  | 12       | 30        |
| 4     | DMF         | 10       | 60        |
| 5     | n-Hexane    | 12       | Trace     |

### Table 3. Antibacterial Activity of Quinoline Derivatives 2 and 4a-g

| Bacteria | Products | Antibiotic |
|----------|----------|------------|
|          | 2   | 4a | 4b | 4c | 4d | 4e | 4f | 4g | CRO\(^d\) |
| IZD\(^a\) | - | 14.4±0.5 | - | 15.2±0.3 | - | 7.5±0.4 | - | 12.8±0.6 | 21.5±0.6 |
| 1633 MIC\(^b\) | - | 512 | - | 1024 | - | 2048 | - | 1024 | 2 |
| MBC\(^c\) | - | 1024 | - | 2048 | - | >2048 | - | 2048 | 2 |
| IZD | 9.4±0.3 | - | - | - | - | - | - | 9.8±0.1 | - |
| 1240 MIC | 1024 | - | - | - | - | - | - | 2048 | - |
| MBC | 2048 | - | - | - | - | - | - | >2048 | - |
| IZD | - | - | - | 15.7±0.5 | 10.2±0.7 | 10.6±0.2 | - | 14.0±0.4 | 18.5±0.3 |
| 1435 MIC | - | - | - | 1024 | 256 | 1024 | - | 1024 | 0.5 |
| MBC | - | - | - | 2048 | 512 | 2048 | - | 1024 | 2 |
| IZD | - | - | - | 11.5±0.1 | - | - | - | - | 18.3±0.4 |
| 1778 MIC | - | - | - | 2048 | - | - | - | - | 1 |
| MBC | - | - | - | >2048 | - | - | - | - | 2 |
| IZD | - | - | - | 12.3±0.4 | - | - | - | - | 15.3±0.7 |
| 1189 MIC | - | - | - | 512 | - | - | - | - | 4 |
| MBC | - | - | - | 1024 | - | - | - | - | 16 |
| IZD | 10.2±0.2 | 14.7±0.1 | 10.6±0.8 | 19.8±0.6 | 14.9±0.3 | 15.2±0.2 | 11.9±0.5 | 14.3±0.3 | 25.7±0.6 |
| 1023 MIC | 1024 | 256 | 2048 | 256 | 1024 | 512 | 1024 | 1024 | 0.25 |
| MBC | 2048 | 512 | >2048 | 512 | 2048 | 1024 | 2048 | 2048 | 0.5 |
| IZD | - | - | - | 17.6±0.4 | 12.7±0.2 | 9.8±0.2 | 14.3±0.5 | 11.5±0.1 | 34.1±0.5 |
| 1234 MIC | - | - | - | 512 | 1024 | 2048 | 512 | 1024 | 2 |
| MBC | - | - | - | 1024 | 2048 | >2048 | 1024 | 2048 | 4 |
| IZD | - | - | - | - | - | - | - | 11.2±0.2 | - |
| 1079 MIC | - | - | - | - | - | - | - | 2048 | - |
| MBC | - | - | - | - | - | - | - | >2048 | - |

Note: \(^a\)Values reported as mm, \(^b\)Values reported as μg mL\(^{-1}\), \(^c\)Values reported as μg mL\(^{-1}\), \(^d\)Ceftriaxone, -: No noticeable antibacterial effect at initial concentrations.
heterocycles 2 and 4a-g, as well as antibiotic ceftiraxone were evaluated against a variety of pathogenic bacteria. The results are recorded as IZD, MIC, and MBC values in Table 3.

**Discussion**

In vitro antibacterial potentials of all synthesized heterocyclic derivatives were studied and compared with those of ceftiraxone. All of our synthesized heterocycles could inhibit the growth of *B. subtilis* subsp. *spizizenii*. The blocking effects against *E. faecalis* and *S. aureus* were observed with only quinoline Schiff base 4c containing 2-hydroxyaniline substituent. The quinoline 4g bearing 4-hydroxyaniline substituent was the only effective heterocycle and the only Schiff base derivative on gram-negative *Proteus vulgaris* and gram-positive *S. pneumoniae*, respectively. Moreover, the heterocyclic compounds 4c and 4g affected a wider range of tested bacterial strains. Schiff bases prepared by the condensation of 2-chloro quinoline-3-carbaldehyde derivatives and a substituted 5-benzimidazolecarboxylic hydrazide could inhibit *E. coli* strains with MICs in the range of 25 to 50 μg mL⁻¹ (12). Cu (II) complexes of 2-sulfanyl or 2-hydroxyquinoline-3-carbaldehyde Schiff bases exhibited better antibacterial effects than their corresponding ligands (14). Furthermore, moderate antibacterial activities were observed with two synthesized Schiff bases based on 2-chloroquinoline-3-carbaldehyde (15). It has been found that quinolone and fluoroquinolone antibiotics block the growth of bacteria via enzyme inhibition (31). DNA gyrase and topoisomerase IV as DNA topology controllers are two essential enzymes produced by the most bacteria whose function is impaired in the presence of quinolones and fluoroquinolones. They also play a key role in the repair, deactivation, replication, and transcription of DNA. In addition, molecular docking studies predicted effective interactions of 6-chloro-2-hydroxyquinoline-3-carbaldehyde Schiff bases introduced into the active site of target protein (13).

**Conclusion**

To conclude, synthesized 2-chloroquinoline-3-carbaldehyde Schiff bases showed moderate inhibitory properties against some important pathogenic gram-negative and gram-positive strains. Changes in the structure and position of substituents on quinoline ring, complexation, and the use of new condensing primary amines and their equivalents may improve antimicrobial effects.

**Authors’ Contributions**

HB supervised the synthetic and antibacterial parts and analyzed the microbial data. HHM synthesized title heterocycles. GB supervised the synthetic part and designed target compounds. RA analyzed the chemical data. MMM collaborated in antibacterial part.

**Conflict of Interest Disclosures**

No conflict of interests was declared by the authors.

**Ethical Issues**

All synthetic and biological tests were performed in accordance with the laws approved by the Ethics Committee of University of Zabol, Zabol, Iran.

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**References**

1. Amchova P, Kotolova H, Rudá-Kucerová J. Health safety issues of synthetic food colorants. Regul Toxicol Pharmacol. 2015;73(3):914-22. doi: 10.1016/j.yrtph.2015.09.006.
2. Filppula AM, Neuvonen PJ, Backman JT. In vitro assessment of time-dependent inhibitory effects on CYP2C8 and CYP3A activity by fourteen protein kinase inhibitors. Drug Metab Dispos. 2014;42(7):1202-9. doi: 10.1124/dmd.114.057695.
3. Kverno T, Houben J, Sytle I. Receptor-binding and pharmacokinetic properties of dopaminergic agonists. Curr Top Med Chem. 2008;8(12):1049-67. doi: 10.2174/156802608785161457.
4. Gillespie RJ, Adams DR, Bebbington D, Benwell K, Cliffe IA, Dawson CE, et al. Antagonists of the human adenosine A2A receptor. Part 1: discovery and synthesis of thieno [3,2-d] pyrimidine-4-methanone derivatives. Bioorg Med Chem Lett. 2008;18(9):2916-9. doi: 10.1016/j.bmcl.2008.03.075.
5. Zhu J, Lai K, Brownie R, Babiuk LA, Mutwiri GK. Porcine TLR8 and TLR7 are both activated by a selective TLR7 ligand, imiquimod. Mol Immunol. 2008;45(11):3238-43. doi: 10.1016/j.molimm.2008.02.028.
6. Souto-Padrón T, Lima AP, Ribeiro Rde O. Effects of dibucaine on the endocytic/exocytic pathways in Trypanosoma cruzi. Parasitol Res. 2006;99(4):317-20. doi: 10.1007/s00436-006-0192-1.
7. Nazirkar B, Mandewale M, Yamgar R. Synthesis, characterization and antibacterial activity of Cu (II) and Zn (II) complexes of 5-aminobenzoturan-2-carboxylate Schiff
Antibacterial Effects of 2-Chloro-3-quinolinecarboxaldehyde Schiff Bases

8. Wei L, Tan W, Zhang J, Mi Y, Dong F, Li Q, et al. Synthesis, characterization, and antifungal activity of Schiff bases of inulin bearing pyridine ring. Polymers (Basel). 2019;11(2). doi: 10.3390/polym11020371.

9. Zhang B, Liu Y, Wang Z, Li Y, Wang Q. Antiviral activity and mechanism of gossypol: effects of the O2 – production rate and the chirality. RSC Adv. 2017;7(17):10266-77. doi: 10.1039/C6RA28625A.

10. Kumar S, Bains T, Won Kim AS, Tam C, Kim J, Cheng LW, et al. Highly potent 1H-1, 2, 3-triazole-theretated isatin-metronidazole conjugates against anaerobic foodborne, waterborne, and sexually-transmitted protozoal parasites. Front Cell Infect Microbiol. 2018;8:380. doi: 10.3389/fcimb.2018.00380.

11. Ammerkar ND, Bhongade BA, Bhusari KP. Synthesis and biological evaluation of some 4-(6-substituted-1, 3-benzothiazol-2-yl) amino-1, 3-thiazole-2-amines and their Schiff bases. Araj J Chem. 2015;8(4):343-52. doi: 10.1016/j.arabic.2014.11.034.

12. Mallandur BK, Rangaih G, Harohally NV. Synthesis and antimicrobial activity of Schiff bases derived from 2-chloro quinoline-3-carboxaldehyde and its derivatives incorporating 7-methyl-2-propyl-3H-benzoimidazole-5-carboxylic acid hydrazide. Synth Commun. 2017;47(11):1065-70. doi: 10.1080/00397911.2017.1309668.

13. Mandewale MC, Thorat BR, Shelke D, Yangar R. Fluorescence and molecular docking studies of some new Schiff bases of 6-chloro-2-hydroxyquinoline-3-carboxaldehyde. J Chem Pharm Res. 2015;7(6):900-9.

14. Nath P, Dhumwad SD. Antimicrobial studies of Co (II), Ni (II), Cu (II) and Zn (II) complexes derived from Schiff bases of 3-formyl quinoline and 3-hydrazinoquinoxalin-2 (1H) one. Rasayan J Chem. 2012;5(2):234-8.

15. Abd-El Maksoud MA, Tawfik HA, Soliman FM, Moharam ME, Dondeti MF. Synthesis, antimicrobial and molecular docking evaluation of some heterocycles containing quinoline moiety. Der Pharma Chem. 2016;8(13):291-301.

16. Pearson WH, Gallagher BM. The intramolecular Schmidt reaction of azides with tertiary alcohols: synthesis of 5-(α-naphthyl)-and 5-(β-naphthyl) indolizidines as potential dopamine analogs and non-opiate antinociceptive agents. Tetrahedron. 1996;52(37):12039-48. doi: 10.1016/0040-4020(96)00723-5.

17. Han L, Xing P, Jiang B. Selective aerobic oxidation of alcohols to aldehydes, carboxylic acids, and imines catalyzed by a Ag-NHC complex. Org Lett. 2014;16(13):3428-31. doi: 10.1021/ol501353q.

18. Blackburn T, Taylor RJK. In situ oxidation– imine formation– reduction routes from alcohols to amines. Org Lett. 2001;3(11):1637-9. doi: 10.1021/ol015819b.

19. Kwon MS, Kim S, Park S, Bosco W, Chidrala RK, Park J. One-pot synthesis of imines and secondary amines by Pd-catalyzed coupling of benzyl alcohols and primary amines. J Org Chem. 2009;74(7):2877-9. doi: 10.1021/jo8026609.

20. Goraya V, Kim HY, Oh K. O-naphthoquinone-catalyzed aerobic oxidation of amines to (Ket) imines: a modular catalyst approach. Org Lett. 2016;18(19):5174-7. doi: 10.1021/acs.orglett.6b02697.

21. Zhang E, Tian H, Xu S, Xu X, Xu Q. Iron-catalyzed direct synthesis of imines from amines or alcohols and amines via aerobic oxidative reactions under air. Org Lett. 2013;15(11):2704-7. doi: 10.1021/ol4010118.

22. Kallitsakis MG, Tancini PD, Dixit M, Mpourmpakis G, Lykakis IN. Mechanistic studies on the Michael addition of amines and hydrazines to nitrostyrenes: nitroalkane elimination via a retro-aza-Henry-type process. J Org Chem. 2018;83(3):1176-84. doi: 10.1021/acs.joc.7b02637.

23. Mir R, Dudding T. A Au(I)-precatalyst with a cyclopentadienyl counterion: an unusual ion pair, J Org Chem. 2016;81(6):2675-9. doi: 10.1021/acs.joc.6b00241.

24. Reddy Ch V, Kingston JV, Verkade JG. (t-Bu2PN=PiBuNCH2CH2)3N: new efficient ligand for palladium-catalyzed C-N couplings of aryl and heteroaryl bromides and chlorides and for vinyl bromides at room temperature. J Org Chem. 2008;73(8):3047-62. doi: 10.1021/jo702367k.

25. Rahimi S, Khoei S, Ghandi M. Preparation and characterization of rod-like chitosan-quinoline nanoparticles as pH-responsive nanocarriers for quercetin delivery. Int J Biol Macromol. 2019;128:279-89. doi: 10.1016/j.ijbiomac.2019.01.137.

26. Beyzaei H, Moghadam-Manesh M, Aryan R, Ghasemi B, Samzadeh-Kermani A. Synthesis and in vitro antibacterial evaluation of 6-substituted 4-amino-pyrazolo(3,4-d) pyrimidines. Chem Pap. 2017;71(9):1683-91. doi: 10.1007/s11696-017-0163-2.

27. Ibrahim NM, Yosef HAA, Mehran MRH. The behavior of 2-chloroquinoline-3-carboxaldehyde towards certain primary amines and activated methylenes. Egypt J Chem. 2010;53(5):673-91. doi: 10.21608/jechem.2010.1257.

28. Nandeshwarappa BP, Manjappa S, Kishore B. A novel approach toward the synthesis of azetidinones derivatives. JSulphur Chem. 2011;32(5):475-81. doi: 10.1080/17415993.2011.601870.

29. Choudhury AR, Paul SB, Choudhury S. Ultrasonic-accelerated synthesis of quinoline-based luminescent imines exhibiting large Stokes shift. Russ J Gen Chem. 2019;89(3):417-23. doi: 10.1021/acs.orglett.9b02257.

30. Mistry BM, Jauhari S. Quinoline-based azetidinone and pyrrolidine analogues as antimicrobial and antituberculosis agents. Med Chem Res. 2013;22(2):647-58. doi: 10.1007/s10044-012-0061-7.

31. PhamTDM, Ziora ZM, Blaskovich MAT. Quinolone antibiotics. Med Chem Commun. 2019;10:1719-39. doi: 10.1039/C9MD00120D.