Antibacterial evaluation and molecular properties of pyrazolo[3,4-b]pyridines and thieno[2,3-b]pyridines

Mervat A. Elsherif1,2*
1Chemistry Department, College of Science, Jouf University, P.O. Box: 2014, Sakaka, Saudi Arabia
2Food Technology Research Institute, Agriculture Research Center, Giza, Egypt

ARTICLE INFO
Received on: 06/12/2020
Accepted on: 11/02/2021
Available online: 05/06/2021

Key words:
Pyrazolo[3,4-b]pyridine, thieno[2,3-b]pyridine, antibacterial activity, molecular properties, drug-likeness.

ABSTRACT
A series of pyrazolo[3,4-b]pyridines (6a-h) and thieno[2,3-b]pyridines (8a-h) was synthesized for the evaluation of their in vitro antibacterial activities against four bacteria species (namely Bacillus subtilis, Staphylococcus aureus, Escherichia coli, and Pseudomonas aeruginosa) and compared the result with the standard drug (Tetracycline). The result of the antibacterial evaluation showed that some pyrazolo[3,4-b]pyridines and thieno[2,3-b]pyridines display moderate antibacterial activity against the four bacteria species in this study. Furthermore, the physicochemical, pharmacokinetic, and drug-likeness properties were carried out using SwissADME website. The results of molecular properties show that all the pyrazolopyridines 6a-h and thienopyridines 8a-h showed agreement with the Lipinski and Veber rules. The two pyrazolo[3,4-b]pyridines 6b and 6c are almost in the range of the bioavailability radar pink area. Also, pyrazolo[3,4-b]pyridine derivatives 6a-h show high gastrointestinal absorption, all the derivatives except 6e are nonsubstrates for P-glycoprotein, and most of the derivatives show CYP isofrom inhibition. This study could be valuable in the discovery of a new series of drugs.

INTRODUCTION
Treatment of infectious diseases remains a worldwide problem because of the increasing multidrug resistance caused by human pathogenic microbes. Therefore, the design of new compounds acting as antibacterial agents is an essential approach to overcome the problem of drug resistance (Shaaban et al., 2019).

Nitrogen heterocyclic compounds (triazine, benzimidazole, pyrazolopyrimidine, pyrazoloquinazoline, pyrazole, pyrazoline, and pyrazolo[1,2,3]triazine) are very important classes of compounds owing to their wide-spectrum of biological activities (Abd El-All et al., 2016; Adole et al., 2020; Chobe et al., 2014; El-Naggar et al., 2018; Hassan et al., 2016, 2017, 2018; Jian et al., 2020; Magd-El-Din et al., 2018). In particular, pyrazolo[3,4-b]pyridines and thieno[2,3-b]pyridines (Elneairy et al., 2000; Mohi-El-Deen et al., 2019; Ravula et al., 2020; Saeedi et al., 2020) and 5-acetyl-4-amino-1-(1,2,4-triazin-3-yl)-pyrazolo[3,4-b]pyridine derivative I showed antibacterial activity with good inhibitions against Staphylococcus aureus and Staphylococcus epidermidis (Ali, 2009). 4-Amino-7,8-dihydropyrido[2′,3′:3,4]pyrazolo[5,1-c]-1,2,4-triazin-3,9-dicarbonitrile II exhibited a remarkable cytotoxic activity against MCF-7 (ERα-dependent) cells (Nafie et al., 2020). Also, N-(6-(2,6-dichloro-3,5-dimethoxyphenyl)-1H-pyrazolo[3,4-b]pyridin-3-yl) benzamide derivative III showed potent and selective Fibroblast growth factor receptor (FGFR) kinase inhibitors (Zhao et al., 2016).

On the other hand, 4-methyl-6-phenyl-thieno[2,3-b]pyridine-2-carbonitrile IV as an example of thieno[2,3-b]pyridine derivatives exhibited a promising growth inhibitory effect toward hepatocellular carcinoma (HepG-2) and breast cancer (MCF-7) lines (Hassan et al., 2019). 6-(Thiophen-2-yl)-4-(trifluoromethyl) thieno[2,3-b]pyridin-3-amine V showed promising antibacterial activity against Gram-positive Bacillus subtilis (Kumar et al., 2017) and 3-amino-5-bromo-4,6-dimethyl-N-(4-sulfamoylephynyl) thieno[2,3-b]pyridine-2-carboxamide (VI) showed potent cytotoxicity against five human cancer cells lines, namely, breast adenocarcinoma (MCF7), hepatocellular carcinoma (HepG2), colon adenocarcinoma (HCT116), nonsmall lung (A549), and prostate (PC3) (Nagib and El-Nassan, 2016) (Fig. 1).

*Corresponding Author
Mervat A. Elsherif, Chemistry Department, College of Science, Jouf University, P.O. Box: 2014, Sakaka, Saudi Arabia; Food Technology Research Institute, Agriculture Research Center, Giza, Egypt. E-mail: Maelsherif@ju.edu.sa

© 2021 Mervat A. Elsherif. This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/).
From the above biological applications of pyrazolo[3,4-b]pyridine and thieno[2,3-b]pyridine derivatives, the purpose of this manuscript is to evaluate the antibacterial activities of pyrazolo[3,4-b]pyridines $6a-h$ and thieno[2,3-b]pyridines $8a-h$ to find potent antibacterial agents. Also, the physicochemical, pharmacokinetic, and drug-likeness properties were carried out (Fig. 2).

**MATERIALS AND METHODS**

**Chemistry**

A series of pyrazolo[3,4-b]pyridines $6a-h$ and thieno[2,3-b]pyridines $8a-h$ were synthesized according to the reported procedure and their spectral data are shown in Table 1 (Elgemeie et al., 1993).

**Antibacterial activities**

*In vitro* antibacterial activities of pyrazolo[3,4-b]pyridines $6a-h$ and thieno[2,3-b]pyridines $8a-h$ were measured against *B. subtilis* and *S. aureus* as Gram-positive bacteria and also against *Escherichia coli* and *Pseudomonas aeruginosa* as...

### Table 1. Spectral data of some pyrazolopyridines $6a-h$ and thienopyridines $8a-h$.

| Compounds | Spectral data |
|-----------|--------------|
| 6a | Yellow; m.p. 295 °C. IR (KBr): ν 3470, 3420, 3400 (NH, and NH) cm$^{-1}$. $^1$H NMR: δ 2.41 (s, 3H, CH$_3$), 2.57 (s, 3H, CH$_3$), 4.82 (s, br, 2H, NH$_2$), 7.12-7.63 (m, 5H, C$_6$H$_5$), 11.40 (s, br, 1H, NH) |
| 6b | Red; m.p. 270 °C. IR (KBr): ν 3548, 3404, 3197 (NH$_2$ and NH) cm$^{-1}$. $^1$H NMR: δ 2.55 (s, 3H, CH$_3$), 2.63 (s, 3H, CH$_3$), 2.69 (s, 3H, CH$_3$), 5.48 (s, br, 2H, NH$_2$), 7.38-7.61 (m, 4H, C$_6$H$_4$), 12.18 (s, br, 1H, NH) |
| 6c | Buff; m.p. 290 °C. IR (KBr): ν 3500, 3420 (NH$_2$ and NH) cm$^{-1}$. $^1$H NMR: δ 2.45 (s, 3H, CH$_3$), 3.58 (s, 3H, CH$_3$), 3.68 (s, 3H, OCH$_3$), 4.90 (s, br, 2H, NH$_2$), 7.30-7.72 (m, 4H, C$_6$H$_5$), 11.81 (s, br, 1H, NH) |
| 6d | Orange; m.p. 280 °C. IR (KBr): ν 3577, 3565, 3414, 3296 (NH$_2$ and NH) cm$^{-1}$. $^1$H NMR: δ 2.64 (s, 3H, CH$_3$), 2.68 (s, 3H, CH$_3$), 5.50 (s, br, 2H, NH$_2$), 7.23-7.67 (m, 4H, C$_6$H$_5$), 12.0 (s, br, 1H, NH) |
| 6e | Orange; m.p. 270 °C |
| 6f | Orange; m.p. > 300 °C |
| 6g | Yellow; m.p. > 300 °C |
| 6h | Green; m.p. > 300 °C |
| 8a | Yellow; m.p. 225 °C. IR (KBr): ν 3577, 3285 (NH$_2$), 1696 (CO) cm$^{-1}$. $^1$H NMR: δ 2.61 (s, 3H, CH$_3$), 2.63 (s, 3H, CH$_3$), 7.26 (s, br, 2H, NH$_2$), 7.36-7.88 (m, 10H, 2C$_6$H$_5$) |
| 8b | Red; m.p. 185 °C |
| 8c | Orange; m.p. 192 °C |
| 8d | Orange; m.p. 197 °C. IR (KBr): ν 3480, 3400 (NH$_2$), 1680 (CO) cm$^{-1}$. $^1$H NMR: δ 2.57 (s, 3H, CH$_3$), 2.61 (s, 3H, CH$_3$), 7.15 (s, br, 2H, NH$_2$), 7.30-7.78 (m, 9H, C$_6$H$_5$ and C$_6$H$_4$) |
| 8e | Orange; m.p. 235 °C. IR (KBr): ν 3577, 3565, 3414, 3296 (NH, and NH) cm$^{-1}$. $^1$H NMR: δ 2.45 (s, 3H, CH$_3$), 3.58 (s, 3H, CH$_3$), 3.68 (s, 3H, OCH$_3$), 4.90 (s, br, 2H, NH$_2$), 7.23-7.67 (m, 4H, C$_6$H$_5$), 12.0 (s, br, 1H, NH) |
| 8f | Orange; m.p. 220 °C |
| 8g | Orange; m.p. 207 °C |
| 8h | Yellow; m.p. 240 °C. IR (KBr): ν 3500, 3380 (NH$_2$), 1690 (CO) cm$^{-1}$. $^1$H NMR: δ 2.95 (s, 3H, CH$_3$), 7.26 (s, br, 2H, NH$_2$), 7.29-7.89 (m, 14H, 2C$_6$H$_5$ and C$_6$H$_4$) |
Gram-negative bacteria species using a modified Kirby–Bauer disk diffusion method (Bauer et al., 1966; Osman et al., 2012). The bacteria were maintained on Meuller–Hinton agar. Dimethyl sulfoxide (DMSO) showed no inhibition zone (IZ). The agar media were incubated at 35°C–37°C for 24–48 hours for bacteria such as B. subtilis, S. aureus, E. coli, and P. aeruginosa. The diameter of the IZ (mm) was measured. Tetracycline is used as a reference for antibacterial activities.

**Molecular properties prediction**

The physicochemical, pharmacokinetic, and drug-likeness properties of pyrazolo[3,4-b]pyridines 6a-h and thieno[2,3-b]pyridines 8a-h were predicted using the SwissADME website (http://swissadme.ch) (Al-Wasidi et al., 2020; Elsherif et al., 2020; Naglah et al., 2020).

**RESULTS AND DISCUSSION**

**Chemistry**

The pyrazolo[3,4-b]pyridines 6a-h and thieno[2,3-b]pyridines 8a-h were prepared according to the reported method (Scheme 1) (Elgemeie et al., 1993). The reaction of 2-cyano(thio)acetamide (1) with arylhydrazones of acetylacetone 2a-d and arylhydrazones of 1-phenylbutane-1,3-dione 2e-h in EtONa/EtOH to yield the corresponding sodium salt of pyridine-2-thiolate 3a-h. Then, the acidification of sodium salt 3a-h gave 1H-pyridine-2-thione derivatives 4a-h. There were two ways; the first way was the reaction of pyridine-2-thione 4a-h with Cl2/CHCl3 to give 2-chloropyridine 5a-h. The compounds 5a-h which reacted with hydrazine hydrate in refluxed ethanol gave the corresponding pyrazolo[3,4-b]pyridines 6a-h.

The structure of 6a-h was established on the basis of spectral data. The IR spectrum of compound 6d shows bands at ν 3,577, 3,565, 3,414, and 3,296 cm⁻¹ due to NH2 and NH groups. Also, 1H-NMR of 6d shows a broad signal at δ = 5.50 ppm assigned to an NH2 group and another broad signal at δ = 12.0 ppm assigned to an NH group.

The second way was the reaction of pyridine-2-thione 4a-h with phenacyl bromide in dry ethanol to give the intermediate 7a-h which was cyclization to form the corresponding thieno[2,3-b]pyridines 8a-h.

The structure of thieno[2,3-b]pyridines 8a-h was established on the basis of spectral data. The IR spectrum of 8a revealed the bands at ν 3,577, 3,565, 3,414, and 3,296 cm⁻¹ due to NH2 and NH groups. Also, 1H-NMR of 8d shows a broad signal at δ = 5.50 ppm assigned to an NH group and another broad signal at δ = 12.0 ppm assigned to an NH group.

The IR spectrum of compound 8a showed bands at ν 3,577, 3,565, 3,414, and 3,296 cm⁻¹ due to NH2 and NH groups. Also, 1H-NMR of 8a showed a broad signal at δ = 5.50 ppm assigned to an NH2 group and another broad signal at δ = 12.0 ppm assigned to an NH group.

The biological evaluation

**In vitro antibacterial activities**

Pyrazolo[3,4-b]pyridines 6a-h and thieno[2,3-b]pyridines 8a-h were screened in vitro for their antibacterial activities against four bacteria species (namely B. subtilis, S. aureus, E. coli, and P. aeruginosa) and compared with tetracycline as the standard drug. The results of antibacterial activities are shown in Table 2 and Figure 3, and we can found the following.

The six pyrazolo[3,4-b]pyridine derivatives (6a, 6b, 6c, 6d, 6g, and 6h) and two thieno[2,3-b]pyridines (8a and 8e) exhibit moderate antibacterial activities (IZ range: 12-14 mm) against Gram-positive B. subtilis bacterial and the rest derivatives show weak activities (IZ ≤ 11 mm).

The three derivatives (6b, 8c, and 8g) exhibit moderate activities (IZ = 12 mm) against S. aureus. In the case of E. coli Gram-negative bacterial, only three pyrazolo[3,4-b]pyridine derivatives (6b, 6d, and 6h) show moderate activities (IZ = 13, 16, and 12 mm, resp.).

For P. aeruginosa bacterial, the pyrazolo[3,4-b]pyridine derivative 6h (IZ = 13 mm) and two thieno[2,3-b]pyridines {8f (IZ = 12 mm) and 8g (IZ = 13 mm)} display moderate activities.
Finally, most of pyrazolo[3,4-b]pyridines and thieno[2,3-b]pyridines are moderately active. Therefore, in the future, we will modify, design, and prepare a new pyrazolo[3,4-b]pyridines and thieno[2,3-b]pyridines to obtain and find more active antibacterial agents.

### Molecular properties

#### Physicochemical properties

The results of the computed physicochemical properties of the pyrazolo[3,4-b]pyridines 6a-h and thieno[2,3-b]pyridines 8a-h are shown in Table 3.
Drug-likeness was used for finding the oral drug candidates and was established based on the physicochemical properties. Lipinski’s filter and Veber’s filter are rule-based filters (Daina et al., 2017; Hassan et al., 2020; Lipinski et al., 2001; Veber et al., 2002).

From Table 3, all the pyrazolopyridines 6a-h and thienopyridines 8a-h showed agreement to Lipinski’s rule and Veber’s rule. Therefore, the two series 6a-h and 8a-h may be used as oral drug candidates.

The bioavailability radar of the pyrazolo[3,4-b]pyridines 6a-h and thieno[2,3-b]pyridines 8a-h displayed a rapid evaluation of drug-likeness.

The bioavailability radar was including lipophilicity, size, polarity, solubility, saturation, and flexibility of the physicochemical properties. The optimal range of these properties was presented by the pink area (Lovering et al., 2009; Ritchie et al., 2011) and the properties of pyrazolo[3,4-b]pyridines 6a-h and thieno[2,3-b]pyridines 8a-h were presented by the red line.

From this study, we can conclude that the red line of two pyrazolo[3,4-b]pyridines 6b and 6c is almost in the range of the pink area. Therefore, the two compounds are nearly predicted orally bioavailable (Fig. 4a and b) and we will modify them to obtain more active antibacterial agents.

Pharmacokinetic properties

The results of the pharmacokinetic properties of pyrazolo[3,4-b]pyridines 6a-h and thieno[2,3-b]pyridines 8a-h are shown in Table 4; we can see the following:

All the pyrazolo[3,4-b]pyridine derivatives 6a-h show high gastrointestinal absorption. But, the thieno[2,3-b]pyridines 8a-h show low GI absorption.

| Compounds | MW | nHBA | nHBD | nRB | TPSA (Å²) | Lipophilicity MLogP | XLOGP3 | Fraction Csp3 |
|-----------|----|------|------|-----|-----------|---------------------|--------|---------------|
| Rule      | <500 | ≤10  | ≤5   | ≤9  | 20 to 130 | ≤-4.15 to -0.7 | -0.7 to +5.0 | ≥0.25 |
| 6a        | 266.30 | 4    | 2    | 2   | 92.31     | 1.92               | 3.01               | 0.14  |
| 6b        | 280.33 | 4    | 2    | 2   | 92.31     | 2.18               | 3.37               | 0.20  |
| 6c        | 296.33 | 5    | 2    | 2   | 101.54    | 1.65               | 2.98               | 0.20  |
| 6d        | 300.75 | 4    | 2    | 2   | 92.31     | 2.45               | 3.64               | 0.14  |
| 6e        | 328.37 | 4    | 2    | 3   | 92.31     | 2.92               | 4.27               | 0.05  |
| 6f        | 342.40 | 4    | 2    | 3   | 92.31     | 3.15               | 4.64               | 0.10  |
| 6g        | 358.40 | 5    | 2    | 4   | 101.54    | 2.62               | 4.24               | 0.10  |
| 6h        | 362.82 | 4    | 2    | 3   | 92.31     | 3.42               | 4.90               | 0.05  |
| 8a        | 384.47 | 4    | 1    | 4   | 108.94    | 2.98               | 6.29               | 0.09  |
| 8b        | 400.50 | 4    | 1    | 4   | 108.94    | 3.19               | 6.66               | 0.13  |
| 8c        | 416.50 | 5    | 1    | 5   | 118.17    | 2.38               | 6.26               | 0.13  |
| 8d        | 420.91 | 4    | 1    | 4   | 108.94    | 3.19               | 6.92               | 0.09  |
| 8e        | 448.54 | 4    | 1    | 5   | 108.94    | 3.82               | 7.55               | 0.04  |
| 8f        | 462.57 | 4    | 1    | 5   | 108.94    | 4.01               | 7.92               | 0.07  |
| 8g        | 478.56 | 5    | 1    | 6   | 118.17    | 3.20               | 7.52               | 0.07  |
| 8h        | 482.98 | 4    | 1    | 5   | 108.94    | 4.01               | 8.18               | 0.04  |

MW = molecular weight; nHBA = number of hydrogen bond acceptors; nHBD = number of hydrogen bond donors; nRB = number of rotatable bonds; TPSA = total polar surface area.

Figure 4. (a) The bioavailability radar of derivative 6b. (b) The bioavailability radar of derivative 6c.

All the pyrazolo[3,4-b]pyridines 6a-h and thieno[2,3-b]pyridines 8a-h are not predicted to penetrate the blood–brain barrier (BBB).
Table 4. Pharmacokinetic properties of pyrazolo[3,4-b]pyridines 6a-h and thieno[2,3-b]pyridines 8a-h.

| Compounds | GI absorption | BBB permeability | P-gp substrate | CYP1A2 inhibitor | CYP2C19 inhibitor | CYP2C9 inhibitor | CYP2D6 inhibitor | CYP3A4 inhibitor |
|-----------|---------------|------------------|----------------|-----------------|------------------|------------------|------------------|------------------|
| 6a        | High          | No               | No             | Inhibitor       | Inhibitor        | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    |
| 6b        | High          | No               | No             | Inhibitor       | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    |
| 6c        | High          | No               | Yes            | Inhibitor       | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    |
| 6d        | High          | No               | No             | Inhibitor       | Inhibitor        | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    |
| 6e        | High          | No               | No             | Inhibitor       | Inhibitor        | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    |
| 6f        | High          | No               | No             | Inhibitor       | Inhibitor        | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    |
| 6g        | High          | No               | No             | Inhibitor       | Inhibitor        | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    |
| 6h        | High          | No               | No             | Inhibitor       | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    |
| 8a        | Low           | No               | No             | Non-inhibitor   | Inhibitor        | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    |
| 8b        | Low           | No               | No             | Non-inhibitor   | Inhibitor        | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    |
| 8c        | Low           | No               | No             | Non-inhibitor   | Inhibitor        | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    |
| 8d        | Low           | No               | No             | Non-inhibitor   | Inhibitor        | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    |
| 8e        | Low           | No               | No             | Non-inhibitor   | Inhibitor        | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    |
| 8f        | Low           | No               | No             | Non-inhibitor   | Inhibitor        | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    |
| 8g        | Low           | No               | No             | Non-inhibitor   | Inhibitor        | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    |
| 8h        | Low           | No               | No             | Non-inhibitor   | Inhibitor        | Non-inhibitor    | Non-inhibitor    | Non-inhibitor    |

GI = gastrointestinal absorption; BBB = blood-brain barrier; P-gp = P-glycoprotein.

All the derivatives, pyrazolo[3,4-b]pyridines 6a-h and thieno[2,3-b]pyridines 8a-h, are non-substrates for P-glycoprotein (P-gp) except the derivative 6c (substrates for P-glycoprotein). Therefore, they have no effect on the central nervous system.

Inhibition of the five major CYP isoforms (CYP1A2, CYP2C19, CYP2C9, CYP2D6, and CYP3A4) is certainly one major cause of pharmacokinetic-related drug–drug interactions. The pyrazolo[3,4-b]pyridine derivatives 6a-h are inhibitors of the CYP1A2 enzyme, while the thieno[2,3-b]pyridine compounds 8a-h are non-inhibitors. All compounds, 6a-h and 8a-h, are inhibitors of the CYP2C19 enzyme except the four derivatives 6c, 8f, 8g, and 8h that are Non-inhibitor. The five compounds, pyrazolo[3,4-b]pyridine 6g and thieno[2,3-b]pyridines 8a-d, are inhibitors of the CYP2C9 enzyme and the rest of the derivatives are non-inhibitors. The two series, pyrazolo[3,4-b]pyridine 6g and thieno[2,3-b]pyridines 8a-d, are non-inhibitors of CYP2D6 and CYP3A4 enzymes (Daina et al., 2017).

CONCLUSION

In this manuscript, a series of pyrazolo[3,4-b]pyridines (6a-h) and thieno[2,3-b]pyridines (8a-h) were synthesized for evaluation of their in vitro antibacterial activities against four bacteria species, namely, B. subtilis, S. aureus, E. coli, and P. aeruginosa. In general, some of pyrazolo[3,4-b]pyridines and thieno[2,3-b]pyridines display moderate antibacterial activities. Furthermore, the result of physicochemical, pharmacokinetic, and drug-likeness properties studies show that (i) all the pyrazolopyridines 6a-h and thienopyridines 8a-h fulfill the requirements of Lipinski and Veber rules and (ii) the two pyrazolo[3,4-b]pyridine derivatives (6b and 6c) almost are predicted orally bioavailable. Also, pyrazolo[3,4-b]pyridine derivatives 6a-h show high gastrointestinal absorption, only the derivative 6c is substrates for P-glycoprotein, and most of the pyrazolopyridines 6a-h and thienopyridines 8a-h show CYP isoforms inhibition.

In the future, these results provide the lead for the design of new derivatives of pyrazolo[3,4-b]pyridine and thieno[2,3-b]pyridine with advanced studies to obtain more potent antibacterial agents.

AUTHOR CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. All the authors are eligible to be an author as per the international committee of medical journal editors (ICMJE) requirements/guidelines.

FUNDING

There is no funding to report.

CONFLICTS OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

ETHICAL APPROVALS

This study does not involve experiments on animals or human subjects.

PUBLISHER’S NOTE

This journal remains neutral with regard to jurisdictional claims in published institutional affiliation.

REFERENCES

Abd El-All AS, Hassan AS, Osman SA, Yosef HAA, Abdel-Hady WH, El-Hashash MA, Atta-Allah SR, Ali MM, El Rashedy AA. Synthesis, characterization and biological evaluation of new fused triazine derivatives based on 6-methyl-3-thioxo-1,2,4-triazin-5-one. Acta Pol Pharm, 2016; 73:79.
Elsherif / Journal of Applied Pharmaceutical Science 11 (06); 2021: 118-124

How to cite this article:
Elsherif MA. Antibacterial evaluation and molecular properties of pyrazolo[3,4-b]pyridines and thieno[2,3-b]pyridines. J Appl Pharm Sci, 2021; 11(06):118–124.