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Thiazole an Attractive Scaffold for Development of Anticancer Agent: A Review

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Shelar Uttam B. *

Department of Chemistry, Shri Shiv Chhatrapati College Junnar, Pune, Maharashtra, India – 410 502.

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ABSTRACT

Thiazole is a heterocycle that contains nitrogen and sulfur as heteroatom in its structure. Thiazole is an attractive heterocycle as it is widely distributed in various drugs. Number derivatives have developed using the Thiazole nucleus which are possessing diverse biological activities like anticancer, antimicrobial, antiulcer, and anti-inflammatory. Two different heteroatoms imparting important physicochemical properties in the thiazole derivatives make them the first choice of various researchers. Here we are summarizing the anticancer potential of some thiazole derivatives which are reported.

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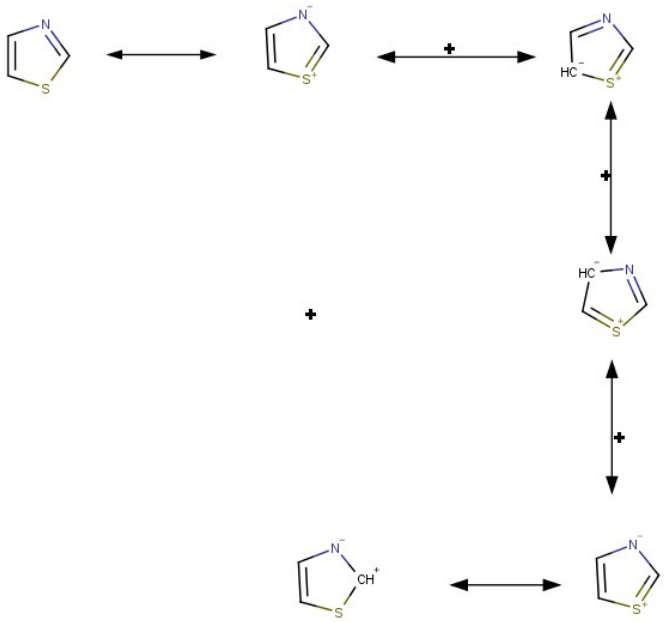
INTRODUCTION:

Thiazole is heterocycles that contain nitrogen and sulfur as heteroatom in its structure. Thiazole is an attractive heterocycle as it is widely distributed in various drugs. Number derivatives have developed using the Thiazole nucleus which are possessing diverse biological activities like anticancer, antimicrobial, antiulcer, and anti-inflammatory. Vitamin Thiamine contains the thiazole nucleus as shown in figure no 1.

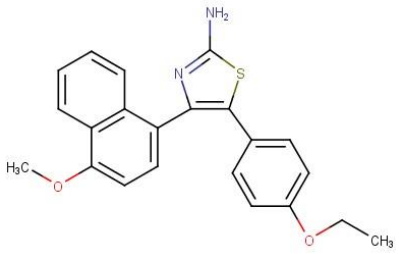
Figure no 1: Thiamine

Resonating structures of the thiazole are still possible and the d orbital sulfur is important to generate different resonating structures as shown in figure no 2.



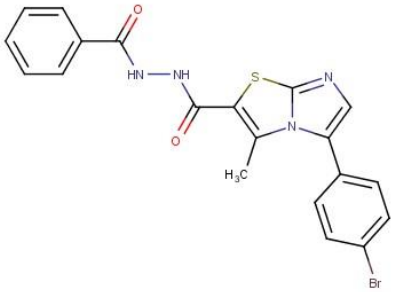
Several drugs are reported to have thiazole nuclei like ritonavir (Antiviral), Sulphathiazole (Antimicrobial), and Abafungin (Antifungal). Here we have summarized some anticancer thiazole derivatives with the most potent derivatives.

Wang *et.al*. (2021) reported the development of novel thiazole-naphthalene as inhibitors of tubulin polymerization with anticancer potential. 5-(4-ethoxyphenyl)-4-(4-methoxynaphthalen-1-yl)-1,3-thiazol-2-amine (1) was found to be the most promising agent from the synthesized series of compounds. This compound was found to arrest the cell cycle in the G2/M phase and its molecular docking studies indicated it is binding to the colchicine binding site.

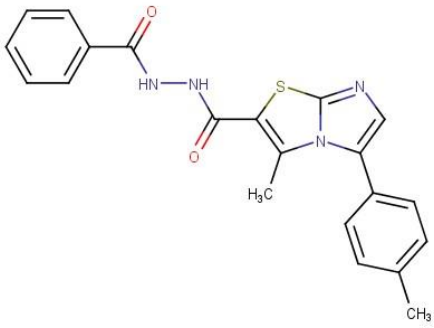


1

El-Subbagh et.al. (2021) reported the development of 3-Methyl-imidazo[2,1-b]thiazole derivatives as a new class of folate inhibitors. They observed that 5-(4-Bromophenyl)-N′ -(benzoyl)-3-methyl-imidazo[2,1-b]thiazole-2- carbohydrazide (2a) and 5-(4-Methylphenyl)-N′ -(benzoyl)-3-methyl-imidazo[2,1-b]thiazole-2- carbohydrazide (2b) was found to be most promising agent both these molecules showed cell cycle arrest and apoptosis. 5-(4-Methylphenyl)-N′ -(benzoyl)-3-methyl-imidazo[2,1-b]thiazole-2- carbohydrazide was found to be reducing body weight and tumor volume.

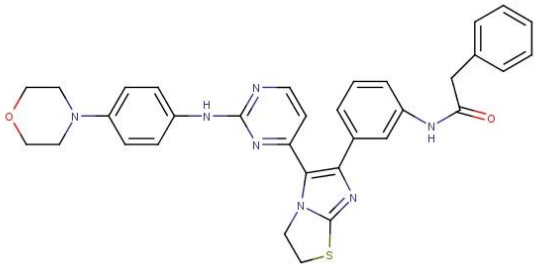


2a



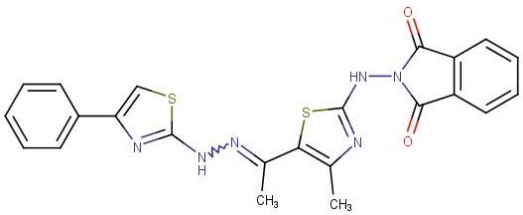
2b

Gadekar et.al. (2021) reported development of 2,3-dihydroimidazo[2,1-b] thiazoles derivatives as new class of dual EGFR and IGF1R inhibitors. They observed that N-{3-[5-(2-{[4-(morpholin-4-yl)phenyl]amino}pyrimidin-4-yl)-2H,3H-imidazo[2,1-b][1,3]thiazol-6-yl]phenyl}-2-phenylacetamide (3) was found to be most promising agent.

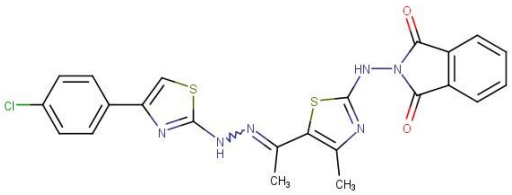


3

Cristina Lima Leite et .al. (2021) reported synthesis of new phthalimido-1,3-thiazole derivatives as carried out their anticancer activity.2-((4-methyl-5-(1-(2-(4-phenylthiazol-2-yl)hydrazono)ethyl) thiazol-2-yl)amino)isoindoline-1,3-dione (4a) and 2-((5-(1-(2-(4-(4-chlorophenyl)thiazol-2-yl)hydrazono)ethyl)-4- methylthiazol-2-yl)amino)isoindoline-1,3-dione (4b) was found to be most active derivatives.

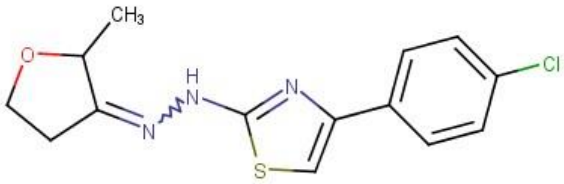


4a

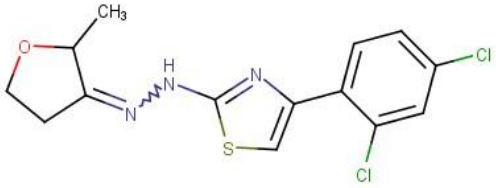


4b

Asım Kaplancıklı et .al. (2021) reported development of thiazole-dihydrofuran as aromatase inhibitors.4-(4-chlorophenyl)-2-(2-(2-methyldihydrofuran-3(2H)-ylidene) hydrazineyl)thiazole (5a) and 4-(2,4-dichlorophenyl)-2-(2-(2-methyldihydrofuran-3(2H)-ylidene)hydrazineyl)thiazole (5b) are most active compounds from the series.

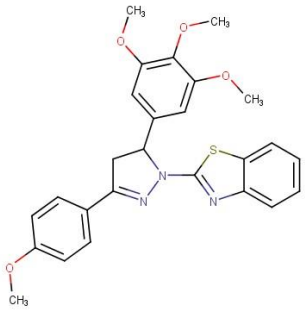


5a



5b

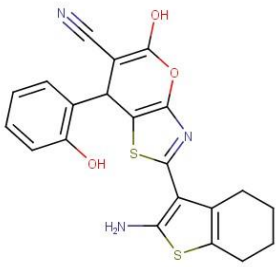
Tugrak et.al. (2020) reported development of 2-(3-(4-methoxyphenyl)-5-(aryl)-4,5-dihydro-1H-pyrazol-1-yl)benzo[d]thiazole as Carbonic anhydrase inhibitors.2-(3-(4-Methoxyphenyl)-5-(3,4,5-trimethoxyphenyl)-4,5-dihydro-1H-pyrazol-1-yl)benzo[d]thiazole (6) is most active compound from the series.



6

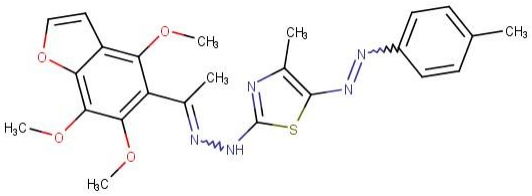
Abdallah et.al. (2019) synthesized novel Pyrano[2,3-d]thiazole and Thiazolo[4,5-b]pyridine compounds acting on c-Met, andPim-1 Kinase. All the compounds showed good anticancer potential 2-(2-amino-4,5,6,7 tetrahydrobenzo[b]thiophen-3-yl)-5-hydroxy-7-(2-hydroxyphenyl)-

7H-pyrano[2,3-d]thiazole-6 carbonitrile (7) was observed to be active against both c-Met, and Pim-1 Kinase.



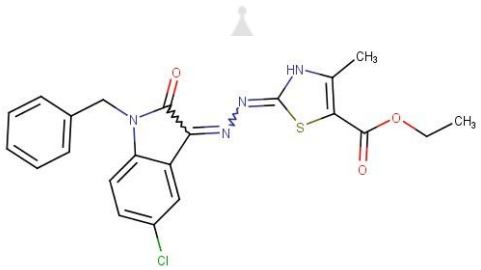
7

Gomha et.al.(2018) reported the development of benzofuran-based thiazole derivatives and carried out their cytotoxic analysis on the human breast cancer cell line. 4-Methyl-5-(p-tolyldiazenyl)-2-(2-(1-(4,6,7-trimethoxybenzofuran-5-yl)ethylidene)hydrazinyl)thiazole (8) was found to be active compound.



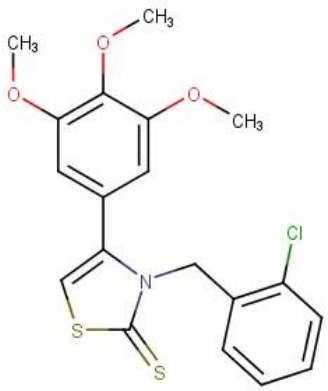
8

Farghaly et.al. (2020) reported 2-indolinone thiazole hybrids as the sunitinib analogs with anti-renal cancer activity. Ethyl 2-((1-benzyl-5-chloro-2-oxoindolin-3-ylidene)hydrazono)-4-methyl-2,3-dihydrothiazole-5-carboxylate (9) was found to be potent compound amongst the synthesized series of compounds.

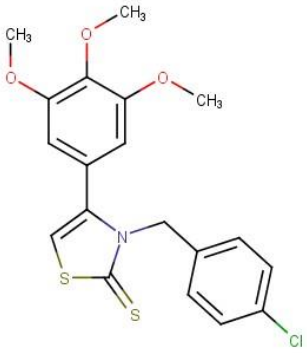


9

Emami et.al. (2019) reported thiazole-2(3H)-thiones containing 4-(3,4,5-trimethoxyphenyl) moiety as anticancer. 3-(2-Chlorobenzyl)-4-(3,4,5-trimethoxyphenyl)thiazole-2(3H)-thione(10a) and 3-(4-Chlorobenzyl)-4-(3,4,5-trimethoxyphenyl)thiazole-2(3H)-thione(10b) are the two promising compounds obtained.

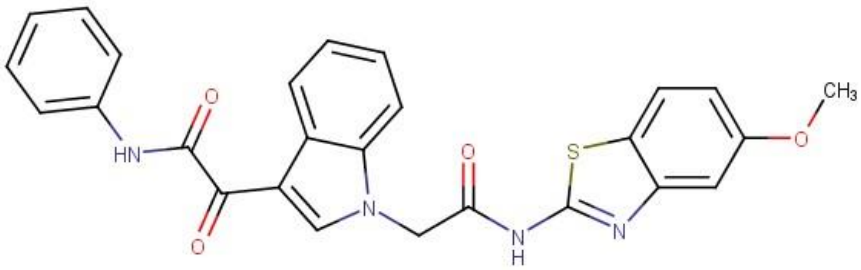


10a



10 b

Nagendra Babu et.al.(2017) reported the development of indolyl-3-glyoxylamide derivatives compounds as tubulin polymerization inhibitors. 2-(1-(2-(5-methoxybenzo[d]thiazol-2-ylamino)-2-oxoethyl)-1H-indol-3-yl)-2-oxo-Nphenylacetamide (11) was found be active compound.



11

SUMMARY:

Thiazole is one of the most prominently utilized heterocycles in medicinal chemistry. Thiazole contains two heteroatoms in its structures which contributes to the various physicochemical as well as biological properties associated with it. Various thiazole derivatives have been reported as anticancer agents and the development of heterocyclic systems based on the thiazole nucleus will be an attractive tool for anticancer drug design and development.

REFERENCES

1. Zhao MY, Yin Y, Yu XW, Sangani CB, Wang SF, Lu AM, Yang LF, Lv PC, Jiang MG, Zhu HL. 2015. Synthesis, biological evaluation and 3D-QSAR study of novel 4,5-dihydro-1H-pyrazole thiazole derivatives as BRAFV600E inhibitors. Bioorganic Med Chem [Internet]. 23(1):46–54. http://dx.doi.org/10.1016/j.bmc.2014.11.029
2. Yamane M, Sawada J ichi, Ogo N, Ohba M, Ando T, Asai A. 2019. Identification of benzo[d]pyrrolo[2,1-b]thiazole derivatives as CENP-E inhibitors. Biochem Biophys Res Commun [Internet]. 519(3):505–511. https://doi.org/10.1016/j.bbrc.2019.09.028
3. Xie W, Wu Y, Zhang J, Mei Q, Zhang Y, Zhu N, Liu R, Zhang H. 2018. Design, synthesis and biological evaluations of novel pyridone-thiazole hybrid molecules as antitumor agents. Eur J Med Chem [Internet]. 145:35–40. https://doi.org/10.1016/j.ejmech.2017.12.038
4. Vasu KK, Digwal CS, Pandya AN, Pandya DH, Sharma JA, Patel S, Agarwal M. 2017. Imidazo[1,2-a]pyridines linked with thiazoles/thiophene motif through keto spacer as potential cytotoxic agents and NF-κB inhibitors. Bioorganic Med Chem Lett [Internet]. 27(24):5463–5466. https://doi.org/10.1016/j.bmcl.2017.10.060
5. Turan-Zitouni G, Altlntop MD, Özdemir A, Kaplanclkll ZA, Çiftçi GA, Temel HE. 2016. Synthesis and evaluation of bis-thiazole derivatives as new anticancer agents. Eur J Med Chem [Internet]. 107:288–294. http://dx.doi.org/10.1016/j.ejmech.2015.11.002
6. Tugrak M, Gul HI, Sakagami H, Gulcin I. 2020. Synthesis, cytotoxic, and carbonic anhydrase inhibitory effects of new 2-(3-(4-methoxyphenyl)-5-(aryl)-4,5-dihydro-1H-pyrazol-1-yl)benzo[d]thiazole derivatives. J Heterocycl Chem. 57(7):2762–2768.
7. Sbenati RM, Semreen MH, Semreen AM, Shehata MK, Alsaghir FM, El-Gamal MI. 2021. Evaluation of imidazo[2,1–b]thiazole-based anticancer agents in one decade (2011–2020): Current status and future prospects. Bioorganic Med Chem [Internet]. 29:115897. https://doi.org/10.1016/j.bmc.2020.115897
8. Romagnoli R, Baraldi PG, Salvador MK, Camacho ME, Preti D, Tabrizi MA, Bassetto M, Brancale A, Hamel E, Bortolozzi R, et al. 2012. Synthesis and biological evaluation of 2-substituted-4-(3′,4′, 5′-trimethoxyphenyl)-5-aryl thiazoles as anticancer agents. Bioorganic Med Chem [Internet]. 20(24):7083–7094. http://dx.doi.org/10.1016/j.bmc.2012.10.001
9. Piechowska K, Świtalska M, Cytarska J, Jaroch K, Łuczykowski K, Chałupka J, Wietrzyk J, Misiura K, Bojko B, Kruszewski S, Łączkowski KZ. 2019. Discovery of tropinone-thiazole derivatives as potent caspase 3/7 activators, and noncompetitive tyrosinase inhibitors with high antiproliferative activity: Rational design, one-pot tricomponent synthesis, and lipophilicity determination. Eur J Med Chem. 175(2019):162–171.
10. Patchipala SB, Pasupuleti VR, Audipudi A V., Bollikolla H babu. 2022. Synthesis, in-vivo anti-diabetic & anticancer activities and molecular modelling studies of tetrahydrobenzo[d]thiazole tethered nicotinohydrazide derivatives. Arab J Chem [Internet]. 15(2):103546. https://doi.org/10.1016/j.arabjc.2021.103546
11. Othman IMM, Alamshany ZM, Tashkandi NY, Gad-Elkareem MAM, Abd El-Karim SS, Nossier ES. 2022. Synthesis and biological evaluation of new derivatives of thieno-thiazole and dihydrothiazolo-thiazole scaffolds integrated with a pyrazoline nucleus as anticancer and multi-targeting kinase inhibitors. RSC Adv. 12(1):561–577.
12. Osmaniye D, Görgülü Ş, Sağlık BN, Levent S, Özkay Y, Kaplancıklı ZA. 2021. Design, synthesis, in vitro and in silico studies of some novel thiazole-dihydrofuran derivatives as aromatase inhibitors. Bioorg Chem. 114(June).
13. Omar AM, Bajorath J, Ihmaid S, Mohamed HM, El-Agrody AM, Mora A, El-Araby ME, Ahmed HEA. 2020. Novel molecular discovery of promising amidine-based thiazole analogues as potent dual Matrix Metalloproteinase-2 and 9 inhibitors: Anticancer activity data with prominent cell cycle arrest and DNA fragmentation analysis effects. Bioorg Chem [Internet]. 101:103992. https://doi.org/10.1016/j.bioorg.2020.103992
14. Oliveira AR, dos Santos FA, Ferreira LP de L, Pitta MG da R, Silva MV de O, Cardoso MV de O, Pinto AF, Marchand P, de Melo Rêgo MJB, Leite ACL. 2021. Synthesis, anticancer activity and mechanism of action of new phthalimido-1,3-thiazole derivatives. Chem Biol Interact. 347(June).

15. Mumtaz A, Shoaib M, Zaib S, Shah MS, Bhatti HA, Saeed A, Hussain I, Iqbal J. 2018. Synthesis, molecular modelling and biological evaluation of tetrasubstituted thiazoles towards cholinesterase enzymes and cytotoxicity studies. Bioorg Chem [Internet]. 78:141–148. https://doi.org/10.1016/j.bioorg.2018.02.024
16. Mirza S, Asma Naqvi S, Mohammed Khan K, Salar U, Choudhary MI. 2017. Facile synthesis of novel substituted aryl-thiazole (SAT) analogs via one-pot multi-component reaction as potent cytotoxic agents against cancer cell lines. Bioorg Chem [Internet]. 70:133–143. http://dx.doi.org/10.1016/j.bioorg.2016.12.003
17. Dawood KM, Eldebss TMA, El-Zahabi HSA, Yousef MH, Metz P. 2013. Synthesis of some new pyrazole-based 1,3-thiazoles and 1,3,4-thiadiazoles as anticancer agents. Eur J Med Chem [Internet]. 70:740–749. http://dx.doi.org/10.1016/j.ejmech.2013.10.042
18. Mermer A. 2020. Design, synthesize and antiurease activity of novel thiazole derivatives: Machine learning, molecular docking and biological investigation. J Mol Struct [Internet]. 1222:128860. https://doi.org/10.1016/j.molstruc.2020.128860
19. Mahmoud HK, Farghaly TA, Abdulwahab HG, Al-Qurashi NT, Shaaban MR. 2020. Novel 2-indolinone thiazole hybrids as sunitinib analogues: Design, synthesis, and potent VEGFR-2 inhibition with potential anti-renal cancer activity. Eur J Med Chem [Internet]. 208:112752. https://doi.org/10.1016/j.ejmech.2020.112752
20. Koppireddi S, Chilaka DRK, Avula S, Komsani JR, Kotamraju S, Yadla R. 2014. Synthesis and anticancer evaluation of 3-aryl-6-phenylimidazo[2,1-b]thiazoles. Bioorganic Med Chem Lett [Internet]. 24(23):5428–5431. http://dx.doi.org/10.1016/j.bmcl.2014.10.030
21. Jagadale SM, Abhale YK, Pawar HR, Shinde A, Bobade VD, Chavan AP, Sarkar D, Mhaske PC. 2020. Synthesis of New Thiazole and Pyrazole Clubbed 1,2,3-Triazol Derivatives as Potential Antimycobacterial and Antibacterial Agents. Polycycl Aromat Compd [Internet]. 0(0):1–22. https://doi.org/10.1080/10406638.2020.1857272
22. Guggilapu SD, Guntuku L, Reddy TS, Nagarsenkar A, Sigalapalli DK, Naidu VGM, Bhargava SK, Bathini NB. 2017. Synthesis of thiazole linked indolyl-3-glyoxylamide derivatives as tubulin polymerization inhibitors. Eur J Med Chem [Internet]. 138:83–95. http://dx.doi.org/10.1016/j.ejmech.2017.06.025
23. Guerrero-Pepinosa NY, Cardona-Trujillo MC, Garzón-Castaño SC, Veloza LA, Sepúlveda-Arias JC. 2021. Antiproliferative activity of thiazole and oxazole derivatives: A systematic review of in vitro and in vivo studies. Biomed Pharmacother. 138(February).
24. Govindaiah S, Naha S, Madhuchakrapani Rao T, Revanasiddappa BC, Srinivasa SM, Parashuram L, Velmathi S, Sreenivasa S. 2021. Sulfated magnesium zirconate catalyzed synthesis, antimicrobial, antioxidant, anti-inflammatory, and anticancer activity of benzo[d]thiazole-hydrazone analogues and its molecular docking. Results Chem [Internet]. 3:100197. https://doi.org/10.1016/j.rechem.2021.100197
25. Gomha SM, Abdelhamid AO, Abdelrehem NA, Kandeel SM. 2018. Efficient Synthesis of New Benzofuran-based Thiazoles and Investigation of their Cytotoxic Activity Against Human Breast Carcinoma Cell Lines. J Heterocycl Chem. 55(4):995–1001.
26. Gadekar PK, Urunkar G, Roychowdhury A, Sharma R, Bose J, Khanna S, Damre A, Sarveswari S. 2021. Design, synthesis and biological evaluation of 2,3-dihydroimidazo[2,1-b]thiazoles as dual EGFR and IGF1R inhibitors. Bioorg Chem [Internet]. 115(June):105151. https://doi.org/10.1016/j.bioorg.2021.105151
27. Fayed EA, Ammar YA, Ragab A, Gohar NA, Mehany ABM, Farrag AM. 2020. In vitro cytotoxic activity of thiazole-indenoquinoxaline hybrids as apoptotic agents, design, synthesis, physicochemical and pharmacokinetic studies. Bioorg Chem [Internet]. 100(May):103951. https://doi.org/10.1016/j.bioorg.2020.103951
28. Farghaly TA, Masaret GS, Muhammad ZA, Harras MF. 2020. Discovery of thiazole-based-chalcones and 4-hetarylthiazoles as potent anticancer agents: Synthesis, docking study and anticancer activity. Bioorg Chem [Internet]. 98:103761. https://doi.org/10.1016/j.bioorg.2020.103761
29. Ewida MA, Ewida HA, Ahmed MS, Allam HA, ElBagary RI, George RF, Georgey HH, El-Subbagh HI. 2021. 3-Methyl-imidazo[2,1-b]thiazole derivatives as a new class of antifolates: Synthesis, in vitro/in vivo bio-evaluation and molecular modeling simulations. Bioorg Chem [Internet]. 115(June):105205. https://doi.org/10.1016/j.bioorg.2021.105205
30. Eryılmaz S, Türk Çelikoğlu E, İdil Ö, İnkaya E, Kozak Z, Mısır E, Gül M. 2020. Derivatives of pyridine and thiazole hybrid: Synthesis, DFT, biological evaluation via antimicrobial and DNA cleavage activity. Bioorg Chem. 95.El-Naggar AM, El-Hashash MA, Elkaeed EB. 2021. Eco-friendly sequential one-pot synthesis,

molecular docking, and anticancer evaluation of arylidene-hydrazinyl-thiazole derivatives as CDK2 inhibitors. Bioorg Chem [Internet]. 108(January):104615. https://doi.org/10.1016/j.bioorg.2020.104615
31. Du L, Wang X, Cui G, Xu B. 2021. Design, synthesis and biological evaluation of novel thiazole-based derivatives as human Pin1 inhibitors. Bioorganic Med Chem [Internet]. 29:115878. https://doi.org/10.1016/j.bmc.2020.115878dos Santos TAR, da Silva AC, Silva EB, de Moraes Gomes PAT, Espíndola JWP, de Oliveira Cardoso MV, Moreira DRM, Leite ACL, Pereira VRA. 2016. Antitumor and immunomodulatory activities of thiosemicarbazones and 1,3-Thiazoles in Jurkat and HT-29 cells. Biomed Pharmacother [Internet]. 82:555–560. http://dx.doi.org/10.1016/j.biopha.2016.05.038
32. Donarska B, Świtalska M, Płaziński W, Wietrzyk J, Łączkowski KZ. 2021. Effect of the dichloro-substitution on antiproliferative activity of phthalimide-thiazole derivatives. Rational design, synthesis, elastase, caspase 3/7, and EGFR tyrosine kinase activity and molecular modeling study. Bioorg Chem. 110(July 2020).
33. de Siqueira LRP, de Moraes Gomes PAT, de Lima Ferreira LP, de Melo Rêgo MJB, Leite ACL. 2019. Multi-target compounds acting in cancer progression: Focus on thiosemicarbazone, thiazole and thiazolidinone analogues. Eur J Med Chem [Internet]. 170:237–260. https://doi.org/10.1016/j.ejmech.2019.03.024
34. de Santana TI, Barbosa M de O, Gomes PAT de M, da Cruz ACN, da Silva TG, Leite ACL. 2018. Synthesis, anticancer activity and mechanism of action of new thiazole derivatives. Eur J Med Chem [Internet]. 144(2018):874–886. https://doi.org/10.1016/j.ejmech.2017.12.040
35. Bhandare RR, S.Munikrishnappa C, Suresh Kumar G V., Konidala SK, Sigalapalli DK, Vaishnav Y, Chinnam S, Yasin H, Al-karmalawy AA, Shaik AB. 2022. Multistep synthesis and screening of heterocyclic tetrads containing furan, pyrazoline, thiazole and triazole (or oxadiazole) as antimicrobial and anticancer agents. J Saudi Chem Soc [Internet]. 26(3):101447. https://doi.org/10.1016/j.jscs.2022.101447
36. Bera Pradip, Aher A, Brandao P, Manna SK, Mondal G, Jana A, Santra A, Jana H, Bera Pulakesh. 2020. Induced apoptosis against U937 cancer cells by Fe(II), Co(III) and Ni(II) complexes with a pyrazine-thiazole ligand: Synthesis, structure and biological evaluation. Polyhedron [Internet]. 182:114503. https://doi.org/10.1016/j.poly.2020.114503
37. Bera Pradip, Aher A, Brandao P, Manna SK, Bhattacharyya I, Pramanik C, Mandal B, Das S, Bera Pulakesh. 2021. Synthesis, structure elucidation and dft study of a new thiazole–pyridine anchored nnn donor and it's cobalt(II) complex: In-vitro antitumor activity against U937 cancer cells, dna binding property and molecular docking study. J Mol Struct [Internet]. 1224(Ii):129015. https://doi.org/10.1016/j.molstruc.2020.129015
38. Baig MF, Nayak VL, Budaganaboyina P, Mullagiri K, Sunkari S, Gour J, Kamal A. 2018. Synthesis and biological evaluation of imidazo[2,1-b]thiazole-benzimidazole conjugates as microtubule-targeting agents. Bioorg Chem [Internet]. 77:515–526. https://doi.org/10.1016/j.bioorg.2018.02.005
39. Ansari M, Shokrzadeh M, Karima S, Rajaei S, Fallah M, Ghassemi-Barghi N, Ghasemian M, Emami S. 2020. New thiazole-2(3H)-thiones containing 4-(3,4,5-trimethoxyphenyl) moiety as anticancer agents. Eur J Med Chem [Internet]. 185:111784. https://doi.org/10.1016/j.ejmech.2019.111784
40. Afifi OS, Shaaban OG, Abd El Razik HA, Shams El-Dine SEDA, Ashour FA, El-Tombary AA, Abu-Serie MM. 2019. Synthesis and biological evaluation of purine-pyrazole hybrids incorporating thiazole, thiazolidinone or rhodanine moiety as 15-LOX inhibitors endowed with anticancer and antioxidant potential. Bioorg Chem [Internet]. 87:821–837. https://doi.org/10.1016/j.bioorg.2019.03.076
41. Abd-Elzaher MM, Labib AA, Mousa HA, Moustafa SA, Ali MM, El-Rashedy AA. 2016. Synthesis, anticancer activity and molecular docking study of Schiff base complexes containing thiazole moiety. Beni-Suef Univ J Basic Appl Sci [Internet]. 5(1):85–96. http://dx.doi.org/10.1016/j.bjbas.2016.01.001
42. Abdel-Maksoud MS, Ammar UM, Oh CH. 2019. Anticancer profile of newly synthesized BRAF inhibitors possess 5-(pyrimidin-4-yl)imidazo[2,1-b]thiazole scaffold. [place unknown]: Elsevier Ltd. https://doi.org/10.1016/j.bmc.2019.03.062
43. Abdel-Aziz SA, Taher ES, Lan P, Asaad GF, Gomaa HAM, El-Koussi NA, Youssif BGM. 2021. Design, synthesis, and biological evaluation of new pyrimidine-5-carbonitrile derivatives bearing 1,3-thiazole moiety as novel anti-inflammatory EGFR inhibitors with cardiac safety profile. Bioorg Chem [Internet]. 111(January):104890. https://doi.org/10.1016/j.bioorg.2021.104890

44. Abdallah AEM, Mohareb RM, Ahmed EA. 2019. Novel Pyrano[2,3-d]thiazole and Thiazolo[4,5-b]pyridine Derivatives: One-pot Three-component Synthesis and Biological Evaluation as Anticancer Agents, c-Met, and Pim-1 Kinase Inhibitors. J Heterocycl Chem. 56(11):3017–3029.