ISSN 1070-3632, Russian Journal of General Chemistry, 2018, Vol. 88, No. 12, pp. 2658–2663. © Pleiades Publishing, Ltd., 2018.

Efficient Synthesis of New Pyrimido[5',4':5,6]pyrano[2,3-*d*]pyrimidine-2,4,6(1*H*,3*H*)-triones via the Tandem Intramolecular Pinner–Dimroth Rearrangement, and Their Antibacterial Activity[1]

M. Asadian[a], A. Davoodnia[a]*, and S. A. Beyramabadi[a]

[a] *Department of Chemistry, Mashhad Branch, Islamic Azad University, Mashhad, 9175687119 Iran*
**e-mail: adavoodnia@mshdiau.ac.ir; adavoodnia@yahoo.com*

Received October 22, 2018
Revised December 3, 2018
Accepted December 3, 2018

Abstract—Synthesis of new 8-alkyl-5-aryl-1,3-dimethyl-5,7-dihydro-2*H*-pyrimido[5',4':5,6]pyrano[2,3-*d*]-pyrimidine-2,4,6(1*H*,3*H*)-triones by the high yield reaction of 7-amino-5-aryl-1,3-dimethyl-2,4-dioxo-1,3,4,5-tetrahydro-2*H*-pyrano[2,3-*d*]pyrimidine-6-carbonitriles with aliphatic carboxylic acids in the presence of $POCl_3$ is presented. It is probable that synthesis of these new products proceeds *via* the tandem intramolecular Pinner–Dimroth rearrangement. The products are characterized by FT-IR, ^1H, and ^{13}C NMR spectra and evaluated for their antibacterial activity against gram +ve bacteria (*Staphylococcus aureus* and *Staphylococcus epidermidis*) and gram –ve bacteria (*Escherichia coli* and *Pseudomonas aeruginosa*) using the disc diffusion method.

Keywords: pyrimido[5',4':5,6]pyrano[2,3-*d*]pyrimidine, carboxylic acids, $POCl_3$, Pinner–Dimroth rearrangement, antibacterial

DOI: 10.1134/S1070363218120290

INTRODUCTION

Compounds containing a fused pyrimidine ring are of considerable importance due to their biological activities such as antimalarial [1], antibacterial [2], antioxidant [3], anticancer [4, 5], antiproliferative [6], and antitubercular [7]. The pyrimidine skeleton is present in DNA bases [8] including cytosine, thymine and uracil, and vitamin B1 [9]. Pyrimidines are known as inhibitors of aurora kinase [10], tyrosine kinase [11], CDK4 [12], and EGFR-TK [13]. These properties stimulated our study of synthesis of new fused pyrimidines by a simple and efficient method [14–16].

Although various tricyclic pyrimidopyranopyrimidines can be constructed from two fused pyranopyrimidine and pyrimidine rings, but there is only a limited number of reports on synthesis of pyrimido[5',4':5,6]-pyrano[2,3-*d*]pyrimidines [17–20], that can also be named as pyrano[2,3-*d*:6,5-*d*']dipyrimidines.

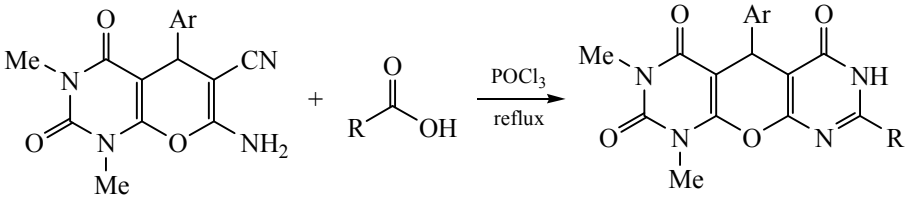
Inspired by the above facts and our ongoing interest in the synthesis of new fused heterocyclic compounds with potential biological activities [21–31], we report herein the synthesis of new 8-alkyl-5-aryl-1,3-dimethyl-5,7-dihydro-2*H*-pyrimido[5',4':5,6]pyrano[2,3-*d*]pyrimidine-2,4,6(1*H*,3*H*)-triones **3a–3g** by the reaction of 7-amino-5-aryl-1,3-dimethyl-2,4-dioxo-1,3,4,5-tetrahydro-2*H*-pyrano[2,3-*d*]pyrimidine-6-carbonitriles **1a–1c** with aliphatic carboxylic acids **2a–2c** in the presence of $POCl_3$ (Scheme 1). To the best of our knowledge, compounds **3a–3g** have not been reported in the literature. Antibacterial assays of the synthesized compounds **3a–3g** were evaluated against *Staphylococcus aureus* (*S. aureus*, American Type Culture Collection 6538), and *Staphylococcus epidermidis* (*S. epidermidis,* ATCC 12228) as gram +ve and *Escherichia coli* (*E. coli*, ATCC 8739) and *Pseudomonas aeruginosa* (*P. aeruginosa*, ATCC 9027) as gram –ve bacteria, using the disc diffusion method.

RESULTS AND DISCUSSION

7-Amino-5-aryl-1,3-dimethyl-2,4-dioxo-1,3,4,5-tetra-hydro-2*H*-pyrano[2,3-*d*]pyrimidine-6-carbonitriles **1a–1c** were prepared according to the earlier developed method [32]. Initially, a model process between

[1] The text was submitted by the authors in English.

Scheme 1.



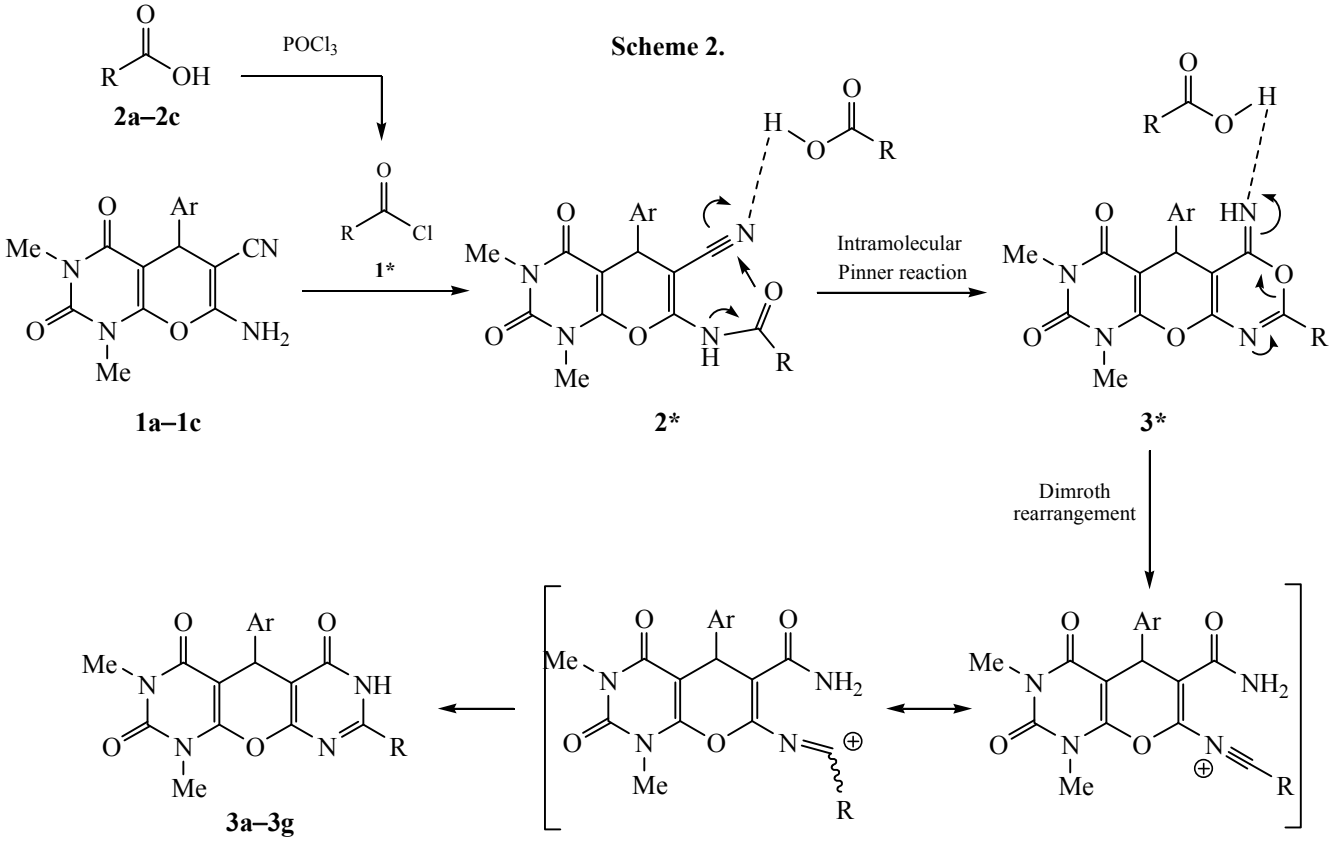
1a–1c **2a–2c** **3a–3g**

Ar = 4-$O_2NC_6H_4$ (**1a**), Ar = 4-ClC_6H_4 (**1b**), Ar = 3-BrC_6H_4 (**1c**), R = Me (**2a**), R = Et (**2b**), R = pentyl (**2c**), Ar = 4-$O_2NC_6H_4$, R = Me (**3a**), Ar = 4-$O_2NC_6H_4$, R = Et (**3b**), Ar = 4-ClC_6H_4, R = Me (**3c**), Ar = 4-ClC_6H_4, R = Et (**3d**), Ar = 4-ClC_6H_4, R = pentyl (**3e**), Ar = 3-BrC_6H_4, R = Et (**3f**), Ar = 3-BrC_6H_4, R = pentyl (**3g**).

7-amino-1,3-dimethyl-5-(4-nitrophenyl)-2,4-dioxo-1,3,4,5-tetrahydro-2*H*-pyrano[2,3-*d*]pyrimidine-6-carbonitrile **1a** and acetic acid was carried out without addition of a solvent and catalyst. After 3 h of refluxing, the limited conversion of the reagents was detected and a large amount of the starting compounds was recovered. The following reaction was carried out in acetic acid in the presence of $POCl_3$. Under such conditions, the reaction proceeded efficiently, and after 2 h of refluxing no initial compounds were detected by TLC, but instead a new single spot was recorded. After following work up, the isolated product was identified as 1,3,8-trimethyl-5-(4-nitrophenyl)-5,7-dihydro-2*H*-pyrimido-[5',4':5,6]pyrano[2,3-*d*]pyrimidine-2,4,6(1*H*,3*H*)-trione **3a**. All subsequent processes of synthesis of compounds **3b–3g** were carried out under the similar conditions.

The structures of new compounds **3a–3g** were deduced from their FT-IR, ^1H and ^{13}C NMR spectral data. For example, the IR spectrum of **3a** was devoid of the CN absorption band at 2206 cm^{-1} recorded for the precursor **1a**, which indicated involvment of the nitrile moiety in the cyclization process. The ^1H NMR spectrum of compound **3a** in DMSO-d_6 demonstrated three singlets at 2.29, 3.09, and 3.41 ppm attributed to three methyl groups, a sharp singlet at 4.87 ppm (CH

Scheme 2.



1a–1c **2*** **3*** **3a–3g**

in pyran ring), two doublets at 7.61 and 8.08 ppm for the protons in *para*-substituted aromatic ring, and a singlet at 12.81 ppm (NH). All the above data indicated formation of the new tricyclic compound **3a**. The ^{13}C NMR spectrum and elemental analysis data were consistent with the assigned structure **3a** with molecular formula $C_{18}H_{15}N_5O_6$.

Based on the earlier reported mechanisms for similar transformations [33-35], a possible mechanism of formation of compounds **3a–3g** is depicted in Scheme 2. Approach to these compounds may proceed via the tandem intramolecular Pinner–Dimroth rearrangement initiated by the respective acyl chloride **1***. Nucleophilic attack of the amino group in compounds **1a–1c** affords the intermediate **2***. Subsequently, the intramolecular Pinner reaction leads to the oxazine intermediate **3*** which then undergoes the Dimroth rearrangement with formation of the final tricyclic products **3a–3g**. Attempts to isolate the proposed intermediates failed even upon close monitoring of the process.

The synthesized compounds **3a–3g** were screened for their antibacterial activity against reference strains of *S. aureus*, *S. epidermidis, E. coli*, and *P. aeruginosa* bacteria. The primary screening test demonstrated that none of the compounds affected gram –ve bacteria, *E. coli,* and *P. aeruginosa*. In case of gram +ve bacteria, growth of *S. aureus* and *S. epidermidis* was inhibited by 3 mg/disc of compounds **3a**, **3c** and **3e**. The inhibition zones of *S. aureus* and *S. epidermidis* bacteria were respectively 9.0±0.0 and 11.0±0.1 mm for **3a**, 10.0±0.and 15.0±0.2 mm for **3c**, and 10.0±0.1 and 13.0±0.0 mm for **3e**. The minimum inhibitory concentration (MIC) was determined to be 3 and 2 mg/mL for **3a**, 2 and 1 mg/mL for **3c** and **3e**, against *S. aureus* and *S. epidermidis* bacteria, respectively. Growth inhibition of *S. aureus* and *S. epidermidis* was also observed for gentamicin (10 μg/disc) as reference compound (20.0±0.5 and 22.0±0.5 mm, respectively). Thus, the antibacterial activity of compounds **3a**, **3c**, and **3e** against tested gram +ve bacteria was satisfactory but lower than that of the standard.

EXPERIMENTAL

All chemicals were purchased from Merck and Aldrich and used without additional purification. Melting points were recorded on a Stuart SMP3 (UK) melting point apparatus. IR spectra were recorded for KBr disks on a Bruker Tensor 27 (Billerica, Massachusetts, USA) spectrophotometer. ^{1}H NMR (300 MHz) and ^{13}C NMR (75 MHz) spectra were measured on a Bruker 300 FT (Billerica, Massachusetts, USA) spectrometer using DMSO-d_6 as a solvent and TMS as an internal standard. Elemental analysis was performed on a Thermo Finnigan Flash EA (Milan, Italy) microanalyzer.

Synthesis of 8-alkyl-5-aryl-1,3-dimethyl-5,7-dihydro-2*H*-pyrimido[5',4':5,6]pyrano[2,3-*d*]pyrimidine-2,4,6(1*H*,3*H*)-triones 3a–3g. A mixture of 7-amino-5-aryl-1,3-dimethyl-2,4-dioxo-1,3,4,5-tetrahydro-2*H*-pyrano[2,3-*d*]pyrimidine-6-carbonitrile **1a–1c** (1 mmol) and an aliphatic carboxylic acid **2a–2c** (1 mL) in $POCl_3$ (0.5 mL) was refluxed for 2 h. Upon completion of the process, the mixture was poured into cold water and neutralized by 25% ammonia solution. Then, the precipitate was collected, washed with water and recrystallized from THF to afford the corresponding compounds **3a–3g**.

1,3,8-Trimethyl-5-(4-nitrophenyl)-5,7-dihydro-2*H*-pyrimido[5',4':5,6]pyrano[2,3-*d*]pyrimidine-2,4,6(1*H*,3*H*)-trione (3a). Light brown crystals, yield 89%, mp >350°C. IR spectrum, ν, cm^{-1}: 3435, 2928, 1650, 1489, 1350, 1236, 1176, 1043, 831. ^{1}H NMR spectrum, δ, ppm: 2.29 s (3H, CH_3), 3.09 s (3H, CH_3), 3.41 s (3H, CH_3), 4.87 s (1H, pyran CH), 7.61 d (J = 8.7 Hz, 2H, H_{arom}), 8.08 d (J = 8.7 Hz, 2H, H_{arom}), 12.81 s (1H, NH). ^{13}C NMR spectrum, δ, ppm: 21.42, 28.21, 29.73, 34.63, 89.38, 101.03, 123.45, 130.33, 146.74, 150.52, 151.16, 152.97, 159.69, 160.42, 161.19, 162.23. Found, %: C 54.64; H 3.92; N 17.44. $C_{18}H_{15}N_5O_6$. Calculated, %: C 54.41; H 3.81; N 17.63.

8-Ethyl-1,3-dimethyl-5-(4-nitrophenyl)-5,7-dihydro-2*H*-pyrimido[5',4':5,6]pyrano[2,3-*d*]pyrimidine-2,4,6(1*H*,3*H*)-trione (3b). Cream-coloured crystals, yield 83%, mp >350°C. IR spectrum, ν, cm^{-1}: 3432, 2908, 1695, 1601, 1487, 1385, 1354, 1305, 1227, 1182, 831. ^{1}H NMR spectrum, δ, ppm: 1.19 t (J = 7.5 Hz, 3H, CH_3), 2.59 q (J = 7.5 Hz, 2H, CH_2), 3.11 s (3H, CH_3), 3.45 s (3H, CH_3), 4.90 s (1H, pyran CH), 7.64 d (J = 8.7 Hz, 2H, H_{arom}), 8.11 d (J = 8.7 Hz, 2H, H_{arom}), 12.81 br.s (1H, NH). ^{13}C NMR spectrum, δ, ppm: 11.38, 27.80, 28.21, 29.80, 34.69, 89.37, 101.24, 123.44, 130.37, 146.73, 150.52, 151.16, 152.99, 159.85, 161.17, 162.26, 164.37. Found, %: C 55.21; H 4.29; N 17.19. $C_{19}H_{17}N_5O_6$. Calculated, %: C 55.47; H 4.17; N 17.02.

5-(4-Chlorophenyl)-1,3,8-trimethyl-5,7-dihydro-2*H*-pyrimido[5',4':5,6]pyrano[2,3-*d*]pyrimidine-

2,4,6(1*H*,3*H*)-trione (3c). White crystals, yield 93%, mp >350°C. IR spectrum, ν, cm^{-1}: 3433, 2964, 1690, 1643, 1486, 1378, 1233, 1179, 1090, 840. ^1H NMR spectrum, δ, ppm: 2.31 s (3H, CH_3), 3.12 s (3H, CH_3), 3.43 s (3H, CH_3), 4.77 s (1H, pyran CH), 7.29 d (J = 8.6 Hz, 2H, H_{arom}), 7.35 d (J = 8.6 Hz, 2H, H_{arom}), 12.77 br (1H, NH). ^{13}C NMR spectrum, δ, ppm: 21.39, 28.21, 29.67, 33.81, 89.97, 101.72, 128.23, 130.72, 131.62, 142.66, 150.52, 152.74, 159.55, 160.02, 161.16, 162.26. Found, %: C 55.67; H 3.82; N 14.64. $C_{18}H_{15}ClN_4O_4$. Calculated, %: C 55.89; H 3.91; N 14.49.

5-(4-Chlorophenyl)-8-ethyl-1,3-dimethyl-5,7-dihydro-2*H*-pyrimido[5',4':5,6]pyrano[2,3-*d*]pyrimidine-2,4,6(1*H*,3*H*)-trione (3d). Cream-coloured crystals, yield 84%, mp >350°C. IR spectrum, ν, cm^{-1}: 3429, 2907, 1692, 1600, 1487, 1384, 1298, 1224, 1180, 1087, 841. ^1H NMR spectrum, δ, ppm: 1.16 t (J = 7.5 Hz, 3H, CH_3), 2.55 q (J = 7.5 Hz, 2H, CH_2), 3.09 s (3H, CH_3), 3.40 s (3H, CH_3), 4.73 s (1H, pyran CH), 7.25 d (J = 8.5 Hz, 2H, H_{arom}), 7.32 d (J = 8.5 Hz, 2H, H_{arom}), 12.72 br (1H, NH). ^{13}C NMR spectrum, δ, ppm: 11.38, 27.36, 28.18, 29.71, 33.87, 89.93, 101.92, 128.20, 130.76, 131.62, 142.64, 150.49, 152.72, 159.66, 161.12, 162.26, 163.96. Found, %: C 57.20; H 4.15; N 13.82. $C_{19}H_{17}ClN_4O_4$. Calculated, %: C 56.93; H 4.28; N 13.98.

5-(4-Chlorophenyl)-1,3-dimethyl-8-pentyl-5,7-dihydro-2*H*-pyrimido[5',4':5,6]pyrano[2,3-*d*]pyrimidine-2,4,6(1*H*,3*H*)-trione (3e). Dark brown crystals, yield 88%, mp >350°C. IR spectrum, ν, cm^{-1}: 3434, 2955, 1687, 1598, 1483, 1384, 1229, 1179, 1084, 757. ^1H NMR spectrum, δ, ppm: 0.87 t (J = 6.8 Hz, 3H, CH_3), 1.25–1.35 m (4H, $2CH_2$), 1.65 quin (J = 7.3 Hz, 2H, CH_2), 2.54 q (J = 7.7 Hz, 2H, CH_2 overlapped with the solvent), 3.11 s (3H, CH_3), 3.42 s (3H, CH_3), 4.75 s (1H, pyran CH), 7.28 d (J = 8.5 Hz, 2H, H_{arom}), 7.35 d (J = 8.5 Hz, 2H, H_{arom}), 11.99 br (1H, NH). ^{13}C NMR spectrum, δ, ppm: 14.24, 22.20, 26.76, 28.17, 29.70, 31.11, 33.88, 34.35, 89.93, 101.89, 128.20, 130.76, 131.62, 142.64, 150.49, 152.71, 159.61, 161.10, 162.27, 163.24. Found, %: C 59.45; H 5.33; N 12.51. $C_{22}H_{23}ClN_4O_4$. Calculated, %: C 59.66; H 5.23; N 12.65.

5-(3-Bromophenyl)-8-ethyl-1,3-dimethyl-5,7-dihydro-2*H*-pyrimido[5',4':5,6]pyrano[2,3-*d*]pyrimidine-2,4,6(1*H*,3*H*)-trione (3f). White crystals, yield 87%, mp >350°C. IR spectrum, ν, cm^{-1}: 3429, 2902, 1691, 1602, 1485, 1384, 1179, 1072, 776. ^1H NMR spectrum, δ, ppm: 1.19 t (J = 7.6 Hz, 3H, CH_3), 2.59 q (J = 7.6 Hz, 2H, CH_2), 3.13 s (3H, CH_3), 3.43 s (3H, CH_3), 4.75 s (1H, pyran CH), 7.21 t (J = 7.8 Hz, 1H, H_{arom}), 7.30–7.39 m (2H, H_{arom}), 7.52 s (1H, H_{arom}), 12.71 br (1H, NH). ^{13}C NMR spectrum, δ, ppm: 11.35, 27.78, 28.21, 29.76, 34.28, 89.69, 101.72, 121.62, 128.04, 130.02, 130.50, 131.58, 146.30, 150.52, 152.87, 159.75, 161.18, 162.26, 164.08. Found, %: C 51.53; H 3.98; N 12.42. $C_{19}H_{17}BrN_4O_4$. Calculated, %: C 51.25; H 3.85; N 12.58.

5-(3-Bromophenyl)-1,3-dimethyl-8-pentyl-5,7-dihydro-2*H*-pyrimido[5',4':5,6]pyrano[2,3-*d*]pyrimidine-2,4,6(1*H*,3*H*)-trione (3g). Cream-coloured crystals, yield 92%, mp >350°C. IR spectrum, ν, cm^{-1}: 3432, 2936, 1683, 1600, 1480, 1382, 1226, 1174, 777. ^1H NMR spectrum, δ, ppm: 0.87 t (J = 6.8 Hz, 3H, CH_3), 1.25–1.35 m (4H, $2CH_2$), 1.66 quin (J = 7.2 Hz, 2H, CH_2), 2.55 q (J = 7.5 Hz, 2H, CH_2 overlapped with the solvent), 3.12 s (3H, CH_3), 3.43 s (3H, CH_3), 4.74 s (1H, pyran CH), 7.20 t (J = 7.7 Hz, 1H, H_{arom}), 7.30–7.38 m (2H, H_{arom}), 7.51 s (1H, H_{arom}), 12.66 br (1H, NH). ^{13}C NMR spectrum, δ, ppm: 14.26, 22.21, 26.72, 28.20, 29.73, 31.12, 34.29, 34.37, 89.68, 101.68, 121.62, 128.05, 130.01, 130.48, 131.60, 146.29, 150.50, 152.82, 159.67, 161.14, 162.26, 163.36. Found, %: C 54.01; H 4.88; N 11.67. $C_{22}H_{23}BrN_4O_4$. Calculated, %: C 54.22; H 4.76; N 11.50.

Antibacterial activity. Antibacterial activity of the synthesized compounds was assessed by the disc diffusion method according to Clinical and Laboratory Standards Institute (CLSI) guidelines [36] against reference strains of *S. aureus*, *S. epidermidis*, *E. coli*, and *P. aeruginosa* bacteria. Standard blank discs, containing 3 mg of the synthesized compounds, were prepared using DMSO as a solvent. Discs were placed on a Mueller–Hinton agar pre-inoculated with 0.1 mL of every bacterial suspension [turbidity equivalent to McFarland tube no. 0.5 (10^8 CFU/mL)]. Standard commercial disc of gentamicin (10 μg/disc) and a disc containing DMSO were used as positive and negative controls, respectively. All discs were fully dried before the application on bacterial lawn. Plates were incubated aerobically for 18–24 h at 37°C. Diameter of inhibitory zones around the discs was measured in millimeters. All determinations were performed in triplicates, and average value was reported as the inhibition zone (mean±SEM). MIC was determined by the agar dilution method using 24-well-flat bottom tissue culture plates. Different concentrations of compounds were prepared in melted Mueller–Hinton agar. After incubation, MIC was defined as the lowest concentration of a compound that inhibited the growth of bacteria.

CONCLUSIONS

New 8-alkyl-5-aryl-1,3-dimethyl-5,7-dihydro-2*H*-pyrimido[5',4':5,6]pyrano[2,3-*d*]pyrimidine-2,4,6(1*H*,3*H*)-triones **3a–3g** are synthesized by the reaction of 7-amino-5-aryl-1,3-dimethyl-2,4-dioxo-1,3,4,5-tetrahydro-2*H*-pyrano[2,3-*d*]pyrimidine-6-carbonitriles **1a–1c** with aliphatic carboxylic acids **2a–2c** in the presence of $POCl_3$. A tandem intramolecular Pinner–Dimroth rearrangement is the probable approach to formation of the products. According to the antibacterial assay compounds **3a**, **3c**, and **3e** demonstrate satisfactory antibacterial effect on the tested gram +ve bacteria.

ACKNOWLEDGMENTS

This work was supported by Islamic Azad University, Mashhad Branch, Iran.

CONFLICT OF INTEREST

No conflict of interest was declared by the authors.

REFERENCES

1. Singh, K. and Kaur, T., *Med. Chem. Comm.,* 2016, vol. 7, p. 749. doi 10.1039/c6md00084c
2. Kumar, B.S., Lakshmi, P.V.A., Veena, B.S., and Sujatha, E., *Russ. J. Gen. Chem.,* 2017, vol. 87, p. 829. doi 10.1134/S1070363217040260
3. Kabeer, S.A., Reddy, G.R., Sreelakshmi, P., Manidhar, D.M., and Reddy, C.S., *J. Heterocycl. Chem.,* 2017, vol. 54, p. 2598. doi 10.1002/jhet.2856
4. Elkanzi, N.A.A., Morsy, N.M., Aly, A.A., Brown, A.B., and Ramadan, M., *J. Heterocycl. Chem.,* 2016, vol. 53, p. 1838. doi 10.1002/jhet.2495
5. Atapour-Mashhad, H., Tayarani-Najaran, Z., Davoodnia, A., Moloudi, R., and Mousavi, S.H., *Drug Chem. Toxicol.,* 2011, vol. 34, p. 271. doi 10.3109/01480545.2010.545066
6. Atapour-Mashhad, H., Soukhtanloo, M., Massoudi, A., Shiri, A., Parizadeh, S.M., and Bakavoli, M., *J. Heterocycl. Chem.,* 2017, vol. 54, p. 366. doi 10.1002/jhet.2592
7. Desai, N.C., Kotadiya, G.M., and Trivedi, A.R., *Bioorg. Med. Chem. Lett.,* 2014, vol. 24, p. 3126. doi 10.1016/j.bmcl.2014.05.002
8. Qin, X., Liu, X., Hong-Bo, L., Li-Na, Y., and Xiaoya, H., *Biosens. Bioelectron.,* 2013, vol. 42, p. 355. doi 10.1016/j.bios.2012.11.004
9. Zeidler, J., Sayer, B.G., and Spenser, I.D., *J. Am. Chem. Soc.,* 2003, vol. 125, p. 13094. doi 10.1021/ja030261j
10. Kumar, A.K.A., Bodke, Y.D., Sambasivam, G., and Lakra, P.S., *Monatsh. Chem.,* 2017, vol. 148, p. 1767. doi 10.1007/s00706-017-1943-7
11. Chikhale, R., Thorat, S., Choudhary, R.K., Gadewal, N., and Khedekar, P., *Bioorg. Chem.,* 2018, vol. 77, p. 84. doi 10.1016/j.bioorg.2018.01.008
12. Pai, A., Jayashree, B.S., Jeyaprakash, R.S., Kini, S.G., and Lobo, R., *Lat. Am. J. Pharm.,* 2017, vol. 36, p. 1568.
13. Mule, S.N.R., Nurbhasha, S., Kolla, J.N., Jadav, S.S., Jayaprakash, V., Bhavanam, L.R., and Bollikolla, H.B., *Med. Chem. Res.,* 2016, vol. 25, p. 2534. doi 10.1007/s00044-016-1668-x
14. Chechina, N.V., Kolos, N.N., Omelchenko, I.V., and Musatov, V.I., *Chem. Heterocycl. Compd.,* 2018, vol. 54, p. 58. doi 10.1007/s10593-018-2230-1
15. Davoodnia, A., Bakavoli, M., Bashash, M., Roshani, M., and Zhiani, R., *Turk. J. Chem.,* 2007, vol. 31, p. 599.
16. Jubeen, F., Iqbal, S.Z., Shafiq, N., Khan, M., Parveen, S., Iqbal, M., and Nazir, A., *Synth. Commun.,* 2018, vol. 48, p. 601. doi 10.1080/00397911.2017.1408840
17. Rimaz, M., Mirshokraie, A., Khalili, B., and Motiee, P., *Arkivoc,* 2015, vol. 2015, p. 88. doi 10.3998/ark.5550190.p008.896
18. Rimaz, M., Rabiei, H., Khalili, B., and Prager, R.H., *Aust .J. Chem.,* 2014, vol. 67, p. 283. doi 10.1071/CH13438
19. Fedorova, E.V., Kvasha, V.V., Studentsov, E.P., Moskvin, A.V., and Ivin, B.A., *Russ. J. Gen. Chem.,* 2007, vol. 77, p. 589. doi 10.1134/S1070363207040159
20. Kidwai, M., Goyal, R., and Singhal, K., *Indian J. Chem. B,* 2007, vol. 46, p. 1159. doi Not available
21. Roshani, M., Davoodnia, A., Shaker Hedayat, M., and Bakavoli, M., *Phosphorus Sulfur Silicon Relat. Elem*., 2004, vol. 179, p. 1153. doi 10.1080/10426500490459759
22. Davoodnia, A., Bakavoli, M., Mohseni, S., and Tavakoli-Hoseini, N., *Monatsh. Chem.,* 2008, vol. 139, p. 963. doi 10.1007/s00706-007-0844-6
23. Davoodnia, A., Bakavoli, M., Moloudi, R., Khashi, M., and Tavakoli-Hoseini, N., *Chin. Chem. Lett.,* 2010, vol. 21, p. 1. doi 10.1016/j.cclet.2009.09.002
24. Davoodnia, A., Khashi, M., and Tavakoli-Hoseini, N., *Chin. J. Catal.,* 2013, vol. 34, p. 1173. doi 10.1016/S1872-2067(12)60547-6
25. Davoodnia, A., Khashi, M., Tavakoli-Hoseini, N., Moloudi, R., and Zamani, H.A., *Monatsh. Chem.,* 2013, vol. 144, p. 677. doi 10.1007/s00706-012-0847-9
26. Khashi, M., Davoodnia, A., and Chamani, J., *Phosphorus Sulfur Silicon Relat. Elem.,* 2014, vol. 189, p. 839. doi 10.1080/10426507.2013.858253

27. Gholipour, S., Davoodnia, A., and Nakhaei-Moghaddam, M., *Chem. Heterocycl. Compd.,* 2015, vol. 51, p. 808. doi 10.1007/s10593-015-1779-1

28. Tajfirooz, F., Davoodnia, A., Pordel, M., Ebrahimi, M., and Beyramabadi, S.A., *Russ. J. Gen. Chem.,* 2017, vol. 87, p. 2429. doi 10.1134/S1070363217100255

29. Fattahi, M., Davoodnia, A., and Pordel, M., *Russ. J. Gen. Chem.,* 2017, vol. 87, p. 863. doi 10.1134/S1070363217040326

30. Khoramdelan, F., Davoodnia, A., Bozorgmehr, M.R., and Ebrahimi, M., *Russ. J. Gen. Chem.,* 2017, vol. 87, p. 2961. doi 10.1134/S1070363217120386

31. Hosseininasab, N., Davoodnia, A., Rostami-Charati, F., Tavakoli-Hoseini, N., and Khojastehnezhad, A., *J. Heterocycl. Chem.,* 2018, vol. 55, p. 161. doi 10.1002/jhet.3019

32. Gholipour, S., Davoodnia, A., and Nakhaei-Moghaddam, M., *Der. Pharma. Chemica.,* 2015, vol. 7, p. 368.

33. Tang, J.H., Shi, D.X., Zhang, L.J., Zhang, Q., and Li, J.R., *Synth. Commun.,* 2010, vol. 40, p. 632. doi 10.1080/00397910902908822

34. Chai, H., Li, J., Yang, L., Lu, H., Qi, Z., and Shi, D., *RSC Adv.,* 2014, vol. 4, p. 44811. doi 10.1039/c4ra08031a

35. Karimi, N., Davoodnia, A., and Pordel, M., *Heterocycl. Commun.,* 2018, vol. 24, p. 31. doi 10.1515/hc-2017-0228

36. Clinical and Laboratory Standards Institute. Performance Standards for Antimicrobial Susceptibility Testing Twentieth Informational Supplement. Clinical and Laboratory Standards Institute, Wayne, P.A, CLSI document M100-S20. Available at: http://www.clsi.org (Accessed October 22, 2018).