# SYNTHESIS AND CHARACTERIZATION OF NEW THIAZOLIDINONES AND 2-OXOPYRROLIDINES DERIVED FROM SCHIFF BASES

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**Keywords:** thiazolidinones; five-membered γ- lactams; imines.

New thiazolidinones and γ- lactams were prepared from mixtures of Schiff base (imine) and thioglycolic acid or phenylsuccinic anhydride, respectively, in moderate yields (52-71 %). The structures of these new thiazolidinones and γ-lactams were established on the basis of the IR, $^{1}$H-NMR,$^{13}$C-NMR, $^{13}$C-NMR DEPT and mass spectral data.

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## Introduction

Thiazolidinones (Figure 1a) are classified as doubly unsaturated five-membered heterocyclic compounds contain one nitrogen, one sulfur and three carbon atoms including a carbonyl group. Thiazolidinones and their derivatives show a large variety of biological activities such as antibiotic, diuretic, tuberculostatic, organoleptic, antileukemic and antiparasitic.[1,2] As far as literature is concerned, only a few information is available about thiazolidinones and their bioactivity. The chemistry of thiazolidin-4-one ring system is considerable interest because it is the core structure in various pharmaceuticals.

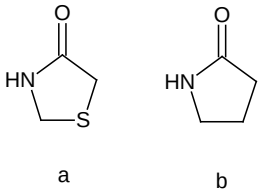



**Figure 1.** Structure of thiazolidinones and 2-oxopyrrolidines (γ-lactams).

Five-membered ring lactams, which are known as γ-lactams or 2-oxopyrrolidines (Figure 1b), are essential structural motifs in biologically active natural products and used in medicines and approved drugs.[3] γ -Lactams have attracted considerable attention in recent years because they are valuable building blocks in the structure of several biologically active molecules.[4] Substituted γ-lactams, in particular, have potential application in drug synthesis, but the development of the stereoselective synthesis of chiral γ-lactams remains a challenge.[5,6] Various γ-lactams are components of natural products,[7] and some biologically important lactams[8] are obtained from the reaction of imines with phenylsuccinic anhydride.

## Experimental part

All solvents were distilled/dried prior to use, whenever this seemed necessary, by standard methods. All solvent extracts were dried over anhydrous sodium sulfate unless otherwise specified.

FT-IR spectra were recorded using a Shimadzu FT-IR spectrophotometer as KBr. The absorption bands of interest are reported and expressed in $cm^{-1}$.

$^{1}$H-NMR spectra were recorded using a Bruker Varian NMR spectrometer (500 MHz). The chemical shift values are expressed in δ(ppm), using tetramethylsilane (TMS) as internal standard and DMSO-$d_6$ as a solvent. $^{13}$C-NMR spectra and $^{13}$C-NMR DEPT spectra were recorded using a Bruker Varian spectrometer (75 MHz). The chemical shift values are expressed in δ(ppm), δ(ppm), using tetramethylsilane (TMS) as internal standard and $CDCl_3$ as a solvent.

Mass spectra were recorded using a 70 eV HPLC-LCQ Fleet/Thermo Scientific instrument with 5973 type mass selective detector.

### General procedure for preparation of imines

In general, the imines (**2a-2d**) were prepared by reaction the corresponding amines with an aldehyde or a ketone in 40 mL of methanol and 4-6 drops of glacial acetic acid with refluxing the reaction mixtures for 1-5 h under stirring. The progress of the reaction is followed by TLC. After completion the reaction, the solvent was evaporated then the residue was recrystallized from a suitable solvent. The physical data of the prepared imines (**2a-2f**) are gathered in Table 1.

### 3-Bromo-2-(pyridin-2-yliminomethyl)phenol (2a)

This compound was prepared by reacting of 2-aminopyridine (0.01 mol, 1 g) with 5-bromo-2-hydroxybenzaldehyde (0.01 mol, 2.4 g). $R_f$=1.2. Yield = 79.6 %, m.p. = 138-139 ºC. IR (KBr disk): 1610 $cm^{-1}$ (C=N).

**3-Bromo-2-(pyridin-3-yliminomethyl)phenol (2b)**

This compound was prepared by reacting of 3-aminopyridine (0.01 mol, 1 g) with 5-bromo-2-hydroxybenzaldehyde (0.01 mol, 2.4 g). $R_f$=0.4, yield was 81.6 %, m.p. = 125-126 ºC. IR (KBr disk): 1615 $cm^{-1}$ (C=N).

**4-(5-Aminonaphthalenylimino)pentan-2-one (2c)**

This compound was prepared by reacting of 1,5-diamino naphthalene (0.006 mol, 1 g) with acetylacetone (0.006 mol, 0.63 g ,0.65ml). $R_f$=0.5., Yield = 52.6 %, m.p = 200 ºC. IR (KBr disk): 1612 $cm^{-1}$ (C=N).

**4-(4-Aminophenylimino)pentan-2-one (2d)**

This compound is prepared by reacting of p-phenylenediamine (0.0099 mol, 1 g) with acetylacetone (0.0099 mol, 0.93 g, 0.95 ml). $R_f$=0.5, yield = 90.9 %, m.p = 94-95 ºC. IR (KBr disk): 1601 $cm^{-1}$ (C=N).

**4-(Pyridin-3-ylimino)pentan-2-one (2e)**

This compound was prepared by reacting of 3-aminopyridine (0.01 mol, 1 g) with acetylacetone (0.01 mol, 1.06 g, 1.09 ml). $R_f$=2, yield = 93.5 %, b.p. = 129-132 ºC. IR (KBr disk): 1612 $cm^{-1}$ (C=N).

**3-(4-Chlorobenzylideneimino)pyridine (2f)**

This compound was prepared by reacting of 3-aminopyridine (0.006 mol, 1 g) with p-chlorobenzaldehyde (0.006 mol, 2.54 g). $R_f$=2, yield = 97 %, m.p = 73-74 ºC. IR (KBr disk): 1623 $cm^{-1}$ (C=N).

**General procedure for preparation of thiazolidinones (3)**

A mixture of compound **2a-2d** and thioglycolic acid in chloroform (15) ml was allowed to react in a Teflon beaker in a microwave oven at 100 W for 6-12 minutes. Progress of the reaction is checked by TLC using hexane-ethyl acetate as eluent. After the completion of reaction, chloroform was removed by distillation to give a solid residue. The solids were washed successively with 1 N HCl (20 mL), water (2×20 mL), 5% $NaHCO_3$ (20 mL) and brine (20 mL). The organic layer was dried with $Na_2SO_4$ The solvent was removed by evaporation. The following thiazolidinones were prepared:

**2-(2-Bromo-6-hydroxyphenyl)-3-(pyridin-2-yl)-thiazolidin-4-one (3a)**

This compound was prepared by reacting **2a** (0.003 mol, 1 g) and (0.003 mol, 0.33 g, 0.25 mL) of thioglycolic acid. $R_f$=0.7, yield = 63 %, m. p. = 88-89 ºC. IR (KBr disk): 1673 $cm^{-1}$ (–N–C=O). $^1$H-NMR (500MHz, DMSO-$d_6$, δ, ppm) 3.81(d, 1H), 4.19(d, 1H), 5.68(s, 1H), 6.15-7.51 (m, 3H), 6.09-8.12 (m, 4H) and 10.21 (s, 1H). $^{13}$C-NMR (75 MHz, $CDCl_3$, δ, ppm) 38.65, 48.02, 122.03-151.02 and 177.86

**2-(2-Bromo-6-hydroxyphenyl)-3-(pyridin-3-yl)thiazolidin-4-one (3b)**

This compound was prepared by reacting **2b** (0.003 mol, 1 g) and (0.003 mol, 0.33 g, 0.25 mL) of thioglycolic acid. $R_f$=1.2, yield = 71 %, m. p. = 98-99 ºC. IR (KBr disk): 1672 $cm^{-1}$ (–N–C=O). 1H-NMR (500 MHz, DMSO-$d_6$, δ, ppm) 3.91(d, 1H), 4.31(d, 1H), 5.61(s, 1H), 6.22-7.51 (m, 3H), 6.01-8.12 (m, 4H) and 10.26 (s, 1H). $^{13}$C NMR (75 MHz. $CDCl_3$, δ, ppm) 42.96, 52.12, 128.13-133.30, 135.95-151.34 and 180.52.

**3-(5-Aminonaphthalen-1-yl)-2-methyl-2-(2-oxopropyl)-thiazolidin-4-one (3c)**

This compound was prepared by reacting **2c** (0.001 mol, 0.41 g) and (0.001 mol, 0.157 g, 0.12 mL) of thioglycolic acid. $R_f$=0.6, Yield = 69 %, m. p. = 139-140 ºC. IR (KBr disk): 1676 $cm^{-1}$ (–N–C=O). 1H NMR (500 MHz, DMSO-$d_6$, δ,ppm) 3.88 (d, 1H), 4.07 (d, 1H), 1.90 (s, 3H), 2.79 (s, 3H), 4.29 (s, 2H), 4.60 (s, 2H) and 7.30-8.02 (m, 6H). $^{13}$C-NMR (75 MHz, $CDCl_3$, δ, ppm) 40.80, 61.85, 18.28,26.78, 36.95, 124.44-156.76, 179.17 and 177.86.

**3-(4-Aminophenyl)-2-methyl-2-(2-oxopropyl)-thiazolidin-4-one (3d)**

This compound was prepared by reacting **2d** (0.005 mol, 1 g) and (0.005 mol, 0.48 g, 0.36 mL) of thioglycolic acid. $R_f$=1.2, Yield =57 %, m. p. = 86-87 ºC. IR (KBr disk): 1681 $cm^{-1}$ (–N–C=O). $^1$H NMR (500 MHz, DMSO-$d_6$, δ,ppm) 3.98 (d, 1H), 4.25 (d, 1H), 1.89 (s, 3H), 2.85 (s, 3H), 4.65 (s, 2H), 4.75 (s, 2H) and 7.55-7.73 (m, 4H). $^{13}$C NMR (75 MHz, $CDCl_3$, δ, ppm) 18.38, 26.75, 35.92, 40.82, 61.55, 124.66-152.78, 178.15 and 201.15.

**General procedure of γ-lactams (4)**

In general the γ-lactam were prepared by reaction the mixture of imines 2a, 2b, 2e and 2f) with phenylsuccinic anhydride in 20 mL of chloroform, then the mixture was refluxed for 1-12 h with stirring. The progress of the reaction was followed by TLC. After completion the reaction, the solvent was evaporated and the residue was recrystallized from ethanol. The following γ-lactams were prepared:

**2-(2-Bromo-6-hydroxyphenyl)-5-oxo-3-phenyl-1-(pyridin-2-yl)pyrrolidine-3-carboxylic acid (4a)**

This compound was prepared by reacting **2a** (0.003 mol, 1 g) and (0.003 mol, 0.64 g) of phenylsuccinic anhydride. $R_f$=0.7, yield = 55 %, m. p. = 121-122 ºC. IR (KBr disk): 1638 $cm^{-1}$ (–N–C=O), 1727 $cm^{-1}$ (HO–C=O). $^1$H-NMR (500 MHz, DMSO-$d_6$, δ, ppm) 3.28 (d, 1H), 3.52 (d, 1H), 4.12 (s, 1H), 6.15-6.70 (m, 5H), 7.63-8.35 (m, 7H), 10.31 (s, 1H) and 11.42 (s, 1H). $^{13}$C NMR (75 MHz, $CDCl_3$, δ, ppm) 42.88, 53.02, 59.79, 121.23-158.52, 125.95-135.95, 127.89-138.11, 172.13 and 185.88.

**2-(2-Bromo-6-hydroxyphenyl)-5-oxo-3-phenyl-1-(pyridin-3-yl)pyrrolidine-3-carboxylic acid (4b)**

This compound was prepared by reacting **2b** (0.003 mol, 1 g) and (0.003 mol, 0.64 g) of phenylsuccinic anhydride. $R_f$=0.6, yield = 61 %, m. p. = 113-114 °C. IR (KBr disk): 1655 $cm^{-1}$ (–N–C=O), 1719 $cm^{-1}$ (HO–C=O). $^1$H-NMR (500 MHz, DMSO-$d_6$, δ, ppm) 3.51 (d, 1H), 3.81 (d, 1H), 4.55 (s, 1H), 6.08-6.54 (m, 5H), 7.18-8.02 (m, 7H), 9.98 (s, 1H) and 11.40 (s, 1H). $^{13}$C NMR (75 MHz, $CDCl_3$, δ, ppm) 41.56, 51.07, 57.96, 120.53-152.74, 124.45-133.90, 171.25 and 178.25.

**2-(2-Bromo-6-hydroxy-phenyl)-5-oxo-3-phenyl-1-(pyridin-3-yl)pyrrolidine-3-carboxylic acid (4e)**

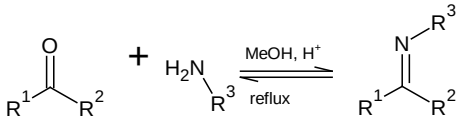
This compound was prepared by reacting **2e** (0.005 mol, 1 g) and (0.005 mol, 1 g) of phenylsuccinic anhydride. $R_f$=0.5, yield = 68.4 %, m. p. = 168-169 °C. IR (KBr disk): 1602 $cm^{-1}$ (–N–C=O), 1697 $cm^{-1}$ (HO–C=O). $^1$H NMR (500 MHz, DMSO-$d_6$, δ, ppm) 3.25 (d, 1H), 3.56 (d, 1H), 1.91 (s, 3H), 2.28 (s, 3H), 3.98 (s, 2H), 6.21-8.08 (m, 9H), and 11.07 (s, 1H). $^{13}$C NMR (75 MHz, $CDCl_3$, δ, ppm) 16.02, 27.23, 37.84, 41.12, 52.11, 59.23, 121.66-157.17, 125.33-139.17, 168.94, 180.73 and 206.85.

**2-(4-Chlorophenyl)-5-oxo-3-phenyl-1-(pyridin-3 -yl)-pyrrolidine-3-carboxylic acid (4f)**

This compound was prepared by reacting **2f** (0.0046 mol, 1 g) and (0.0046 mol, 0.8 g) of phenylsuccinic anhydride. $R_f$=0.1, yield =55 %, m. p. = 159-160 °C. IR (KBr disk): 1602 $cm^{-1}$ (–N–C=O), 1695 $cm^{-1}$ (HO–C=O). $^1$H NMR (500 MHz, DMSO-$d_6$, δ, ppm) 3.32 (d, 1H), 3.56 (d, 1H), 4.53 (s, 1H), 6.21-6.64 (m, 5H), 7.30-8.20 (m, 7H), and 11.40 (s, 1H). $^{13}$C NMR (75 MHz, $CDCl_3$, δ, ppm) 40.13, 51.28, 58.54, 121.67-151.66 124.56-138.54, 169.18 and 183.05.

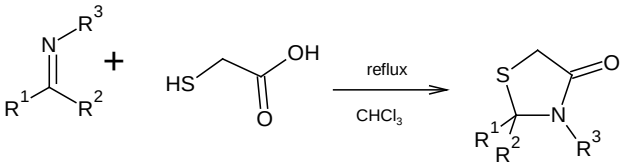
## Results and discussion

The Schiff bases are formed by the condensation of primary amines and an aldehyde or ketone.



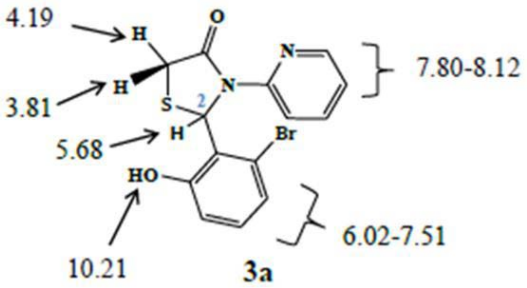

A simple synthetic way to prepare the biologically active thiazolidinones[9,10] is based on the reaction of imines with thioglycolic acid:

The IR spectra of imines **2a-2f** made is characterized by four principal band groups correspond to the stretching vibrations of the aromatic C-H bonds, aliphatic C-H bonds, azomethine bonds (C=N), and aromatic C=C bonds of the and substituted aromatic ring, which occur within the ranges of 3224-3047, 3007-2777, 1638-1610, and 1586-1475 $cm^{-1}$, respectively**.**

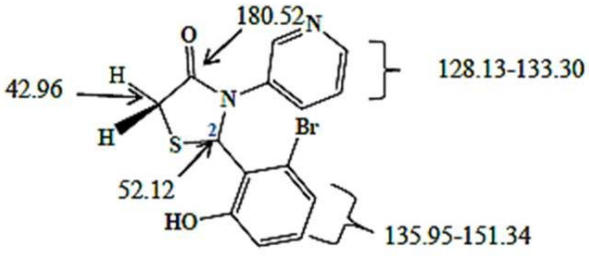



Six band groups can characterize the IR spectra of thiazolidinones 3a-3d correspond to the stretching vibration of the aromatic C-H, aliphatic C-H, carbonyl amide group (N-C=O), aromatic C=C bonds, C-N bonds, and bending vibration of C-S bond, which occurs within the ranges of 3369-3050, 2946-2800, 1720-1672, 1631-1546, 1282-1271 and 778-626 $cm^{-1}$, respectively.

The $^1$H-NMR spectrum of 2-(2-bromo-6-hydroxyphenyl)-3-(pyridin-2-yl)thiazolidin-4-one (**3a**) (see Electronic Supporting Information) is evaluated as an example. The signal at chemical shift δ 2.50-2.51 ppm belongs to the DMSO-$d_6$ solvent. There are two doublet signals at chemical shift δ 3.81 ppm (J=3 Hz) and δ 4.19 ppm (J=3Hz) for methylene protons of thiazolidin-4-one ring (Fig.1). The chiral carbon atom (No.2) gives a singlet signal at δ 5.68 ppm (racemic mixture (R, S) configuration) and there is a multiple signal system for three protons of the phenol ring at δ 6.02-7.51. A multiplet signal for four protons of pyridine ring at δ 7.80-8.12 ppm also appears.

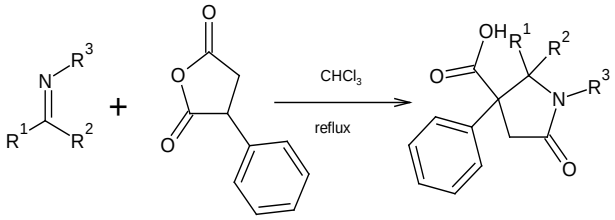



The $^{13}$C NMR spectrum of 2-(2-bromo-6-hydroxyphenyl)-3-(pyridin-3-yl)thiazolidin-4-one (**3a)** as example **(**see Electronic Supplementary Information**)** shows a signal at δ 76.34-76.96 ppm for the $CDCl_3$ solvent. There are two singlets at δ 42.96 ppm and 52.12 for the methylene group carbon and No.2 carbon of the thiazolidin-4-one ring. A multiplet signal between δ 128.13-151.34 ppm for aromatic carbon atoms (pyridine + phenol) ring and a singlet signal at δ 180.52 ppm for the carbon of the amide carbonyl group are also identified.



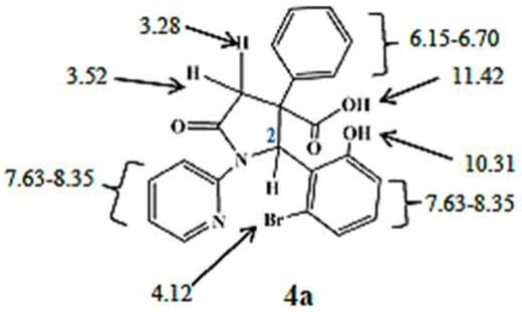
The $^{13}$C-NMR DEPT spectrum of **3a** shows a signal at δ 48 (-) ppm for ($CH_2$), and a signal at δ 38(+) ppm for CH carbon of thiazolidin-4-one ring. There are signals belong to the aromatic region in the range (125-135) (+) ppm and there are signals at δ 122-148 (+) and (177) (+) ppm for the pyridine ring and the amide carbonyl.

γ-Lactams also represent important substructures for the synthesis of biologically relevant compounds in drug discovery[11] and natural products.[12,13] The prevalence of these structures[14,15] resulted in the development of several efficient methods[16] and preparation of diverse libraries of small molecules for biological evaluation.[17,18] Based on these earlier studies, a practical way, the cyclization of imines with phenylsuccinic anhydride in chloroform was followed:




Bands characterize the IR spectra of γ-lactams **4a**, **4b**, **4e** and **4f** belong to the stretching vibrations of the carboxylic OH, aromatic C-H, aliphatic C-H, carboxylic carbonyl group, carbonyl amide group, aromatic C=C and substituted aromatic ring in the ranges of 3134-3026, 3064-2742, 1727-1695, 1651-1586, 1602-1536 and 939-809 $cm^{-1}$, respectively.

The $^1$H-NMR spectrum of 2-(2-bromo-6-hydroxyphenyl)-5-oxo-3-phenyl-1-(pyridin-2-yl)pyrrolidine-3-carboxylic acid (**4a)** (see Electronic Supplementary Information) showed signal at δ 2.57-2.58 ppm belongs to DMSO-$d_6$ solvent. Two doublet signals are appeared at δ 3.28 ppm and 3.52 ppm, (J=4 Hz) for methylene protons of pyrrolidine ring, a singlet at δ 4.12 ppm for the proton of the chiral carbon (No 2) atom (racemic), and two multiplet signals for the five protons of benzene ring at δ 6.15-6.70 and δ 7.63-8.35 for seven aromatic protons of phenol and pyridine rings, respectively.




There are two singlet signals at δ 10.31 ppm and 11.42 ppm of phenol and carboxyl hydroxy groups, respectively.

The mass spectrum of **4a** showed the molecular ion peak in 453,455 m/z and important fragmentation peaks at m/z=452, 454 m/z=424, 426, m/z, 399, 401, m/z= 382, 384, m/z=354, 356 m/z (these fragments contains two bromine isotopes), and fragments without bromine isotopes at m/z, 223, 181 103 78, 77 and 65.

## References

[1]Brown, F. C., 4-Thiazolidinones. *Chem. Rev.*, **1961**, *61*, 463-521. DOI: 10.1021/cr60213a002

[2]Raasch, M. S., 2,2-Bis(polyfluoromethyl)-4-thiazolidinones, -4-oxazolidinones, and -tetrahydro-4H-1,3-thiazin-4-ones, *J. Heterocyclic Chem.*, **1974**, *11*, 587-593. doi.org/10.1002/jhet.5570110424

[3]Younai, A., Chin, G. F., Fettinger, J. C. and Shaw, J. T., Diastereoselective Synthesis of (±)-Heliotropamide by a One-Pot, Four-Component Reaction, *J. Org. Chem.*, **2010**, *75*, 8333. DOI: 10.1021/jo1019317

[4]Nöth, J., Frankowski, K. J., Neuenswander, B., Aubé, J. and Reiser, O., Efficient Synthesis of γ-Lactams by a Tandem Reductive Amination/Lactamization Sequence, *J. Combinat. Chem.*, **2008**, *10*, 456. DOI: 10.1021/cc700202c

[5]Zhao, X., DiRocco, D. A. and Rovis, T., N-Heterocyclic Carbene and Brønsted Acid Cooperative Catalysis: Asymmetric Synthesis of trans-γ-Lactams, *J. Am. Chem. Soc*., **2011**, *133*, 12466-12469. DOI: 10.1021/ja205714g

[6]Comesse, S., Sanselme, M. and Daïch, A., New and Expeditious Tandem Sequence Aza-Michael/Intramolecular Nucleophilic Substitution Route to Substituted γ-Lactams: Synthesis of the Tricyclic Core of (±)-Martinellines, *J. Org. Chem*., **2008**, *73*, 5566-5569. DOI: 10.1021/jo702752w

[7]Manam, R. R., Teisan, S., White, D. J., Nicholson, B., Grodberg,J., Neuteboom, S. T. C., Lam, K. S., Mosca, D. A., Lloyd, G.K. and Potts, B. C. M., Lajollamycin, a Nitro-tetraene Spiro-β-lactone-γ-lactam Antibiotic from the Marine Actinomycete Streptomyces nodosus, *J. Natural Prod*., **2005**, *68*, 240-243. DOI: 10.1021/np049725x

[8]Okazaki, Y., Ishizuka, A., Ishihara, A., Nishioka, T. and Iwamura, H., New Dimeric Compounds of Avenanthramide Phytoalexin in Oats, *J. Org. Chem*., **2007**, *72*, 3830-3839. DOI: 10.1021/jo0701740

[9]Vigorita. M. G., Ottana. R., Monforte. F., Maccari. R., Trovato. A., Monforte. M.T., and Traviano. M.F.; Bioorg.Med.Chem.Lett, 11, 2791, 2001.

[10]Kavitha. C. V., Basappa. S., Swamy .N., Mantelingu. K., Doreswamy. S., Sridhar, M. A., Prasad, S. and Rangappa,.K. S., Synthesis of new bioactive venlafaxine analogs: novel thiazolidin-4-ones as antimicrobials, *Bioorg. Med. Chem.*, **2006**, *14*, 2290. DOI: 10.1016/j.bmc.2005.11.017

[11]Kogure, N., Ishii, N., Kitajima, M., Wongseipipatana, S., Takayama, H., Four Novel Gelsenicine-Related Oxindole Alkaloids from the Leaves of Gelsemium elegans Benth, *Org. Lett*., **2006**, *8*, 3085. DOI: 10.1021/ol061062i

[12]Isaacson, J., Loo, M., Kobayashi, Y., Total Synthesis of (±)-Dysibetaine, *Org. Lett*., **2008**, *10*, 1461-1463. DOI: 10.1021/ol800245m

[13]Ng, P. Y., Tang, Y., Knosp, W. M., Stadler, H. S., Shaw, J. T., Synthesis of diverse lactam carboxamides leading to the discovery of a new transcription-factor inhibitor, *Angew. Chem. Int. Ed*., **2007**, *46*, 5352-5355. DOI: 10.1002/anie.200700762

[14]Kobayashi, J., Inaba, Y., Shiro, M., Yoshida, N., Morita, H., Daphnicyclidins A–H, Novel Hexa- or Pentacyclic Alkaloids from Two Species of Daphniphyllum, *J. Am. Chem. Soc*., **2001**, *123*, 11402. DOI: 10.1021/ja016955e

[15]Lettan, R. B., Galliford, C. V., Woodward, C. C. and Scheidt, K., Amide Enolate Additions to Acylsilanes: In Situ Generation of Unusual and Stereoselective Homoenolate Equivalents, *J. Am. Chem. Soc*., **2009**, *131*, 8805. DOI: 10.1021/ja808811u

[16]Galliford, C. V., Scheidt, K. A., Pyrrolidinyl-spirooxindole natural products as inspirations for the development of potential therapeutic agents, *Angew. Chem. Int Ed*., **2007**, *46*, 748-8758. DOI:10.1002/anie.200701342

[17]Marti, C., Carreira, E. M., Construction of Spiro[pyrrolidine - 3,3′ - oxindoles] − Recent Applications to the Synthesis of Oxindole Alkaloids, *Eur. J. Org. Chem*., **2003**, 2209-2219. doi.org/10.1002/ejoc.200300050

[18]Gonzalez-Lopez, M., Shaw, J. T., Cyclic Anhydrides in Formal Cycloadditions and Multicomponent Reactions, *Chem. Rev*., **2009**, *109*, 164-189. DOI: 10.1021/cr8002714

Received: 11.12.2018.
Accepted: 01.01.2019.