Scientific paper

An Efficient, One-pot Synthesis of Novel 3,5-Disubstituted-1,2,4-Oxadiazoles from Long-Chain Carboxylic Acid Derivatives

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Abstract

A series of novel 3,5-disubstituted-1,2,4-oxadiazoles have been synthesized utilizing either long-chain alkenoates or acyl chlorides with amidoximes in presence of base. The structures of the synthesized compounds were elucidated by IR, mass, ^{1}H and ^{13}C NMR spectroscopy and elemental analysis.

Keywords: 3,5-Disubstituted-1,2,4-oxadiazoles, amidoximes, long-chain alkenoates

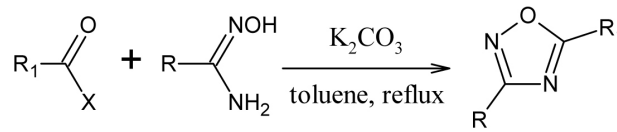
1. Introduction

Azaoxa heterocycles constitute an important class of natural and synthetic products with useful biological activities.[1] 3,5-Disubstituted-1,2,4-oxadiazoles have received considerable attention in the pharmaceutical industry as heterocyclic amide and ester biosteres.[2] The oxadiazole nucleus is a widely studied pharmacophoric scaffold that has emerged as a core structural unit of various muscarinic agonists,[3] benzodiazepine receptor partial agonists,[4] dopamine transporters,[5] a tyrosine kinase inhibitor,[6] a growth hormone secretatogue,[7] and antiinflammatory agents.[8] 1,2,4-oxadiazoles have also shown affinities for serotonin and norepinephrine transporters,[5] and have been used as a urea bioisostere in β_3 adrenergic receptor agonists.[9] Furthermore, derivatives containing 1,2,4-oxadiazole ring systems have been employed as tyrosine kinase inhibitors, serotoninergic (5-HT_3) antiinflammatory agents, antitumor agents, monoamine oxidase inhibitors, coronary artery dilaters, anesthetic agents, muscle relaxants, antischistosomal agents, aldose reductase inhibitors[10] and histamine H3 antagonists.[11] Several methods have been reported in literature for the synthesis of 1,2,4-oxadiazoles.[12]

In continuation of our research[13] we report here a facile, one-pot cyclizations of either carboxylic esters or acyl chlorides with amidoximes into 3,5-disubstituted-1,2,4-oxadiazoles with a long alkenyl chain at C-5. To the best of our awareness this contribution reports for the first time a simple and straightforward synthesis of 1,2,4-oxadiazoles having a long-alkenyl chain attached at C-5 in moderate to excellent yields.

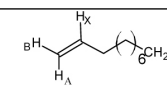
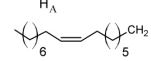
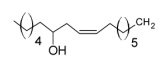
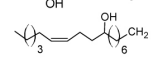
2. Results and Discussion

To explore the probability of getting the pharmacophoric important moiety having a long-chain, we first inve-



2a–e **3a–t**

(Method 1) **1a–d** (X = OMe)
(Method 2) **1'a–d** (X = Cl)

1/1'	R1	2	R
1a, 1'a		2a	CH_3
1b,1'b		2b	
1c,1'c		2c	Cl–CH_2
1d, 1'd		2d	–C_6H_5
		2e	4–OH–C_6H_4

Scheme 1. Synthesis of 3,5-disubstituted-1,2,4-oxadiazoles

Table 1. Synthesis of various 3,5-disubstituted-1,2,4-oxadiazoles.

Entry	Reactant		Product	Method 1		Method 2	
	1a-d/1'a-d	2		Time (h)	Yield (%)	Time (h)	Yield (%)
1	**1a/1'a**	**2a**	**3a**	10	51	1.2	70
2	**1b/1'b**	**2a**	**3b**	10.5	52	1.2	71
3	**1c/1'c**	**2a**	**3c**	10.5	53	1.4	70
4	**1d/1'd**	**2a**	**3d**	11	53	1.4	72
5	**1a/1'a**	**2b**	**3e**	11	50	1.3	72
6	**1b/1'b**	**2b**	**3f**	10	51	1.5	72
7	**1c/1'c**	**2b**	**3g**	11	52	2	79
8	**1d/1'd**	**2b**	**3h**	11	52	2.3	70
9	**1a/1'a**	**2c**	**3i**	10	53	2.4	70
10	**1b/1'b**	**2c**	**3j**	11	54	2.5	71
11	**1c/1'c**	**2c**	**3k**	12	55	2.5	73
12	**1d/1'd**	**2c**	**3l**	12	55	2	74
13	**1a/1'a**	**2d**	**3m**	9	57	1.4	75
14	**1b/1'b**	**2d**	**3n**	9.5	58	1.5	72
15	**1c/1'c**	**2d**	**3o**	10	58	1.2	72
16	**1d/1'd**	**2d**	**3p**	10	51	2	70
17	**1a/1'a**	**2e**	**3q**	12	52	2	71
18	**1b/1'b**	**2e**	**3r**	13	53	2.5	72
19	**1c/1'c**	**2e**	**3s**	13	55	2.5	70
20	**1d/1'd**	**2e**	**3t**	13	56	2.5	71

stigated the one-pot synthesis of 3,5-disubstituted-1,2,4-oxadiazoles from easily prepared long-chain alkenoates **1a-d** and amidoximes **2a-e**. The synthetic pathway followed for the synthesis of 1,2,4-oxadiazoles is presented in the Scheme 1. To a solution of ester in toluene was added amidoxime, followed by addition of K_2CO_3 and the mixture allowed to reflux for 9–13 hours (Scheme 1, Method 1). The one-pot procedure provided compounds **3a-t** in 50–58% yield (Table 1).

When the reactions were performed with more reactive acid chlorides 1'a–d (Scheme 1, Method 2), the reaction times were substantially reduced and yields of the reaction increased. Used acid chlorides (**1'a–d**) are not commercially available and have been synthesized from long-chain carboxylic acids as already reported.[18] Acid chlorides were synthesized *in situ* and after distilling off the excess of thionyl chloride, amidoxime in toluene was added, followed by addition of K_2CO_3. The reaction mixture was heated under reflux and stirred. The compounds **3a–t** were obtained in yields of 79–79% (Table 1).

The reactions with more reactive acid chlorides proceeded with shorter reaction times compared to Method 1. The generality and scope of this synthetic procedure was demonstrated by subjecting aliphatic, vinyl and aromatic amidoximes with olefinic (terminal and internal) and hydroxy olefinic carboxylic acid derivatives.

The compounds were characterized by IR, mass, ^{1}H and ^{13}C NMR spectroscopy and elemental analysis. For instance, IR absorptions at 1660 (C=N) and 1440 cm^{-1} (C–O) were obtained for 3-methyl-5-(dec-9-enyl)-1,2,4-oxadiazole (**3a**). ^{1}H NMR spectra showed absorption of methine proton of C–10 at δ 5.82. C–11 methylene absorption designated as H_A and H_B displayed two distinct δ values when coupled with adjacent C–10 methine protons. The spectrum showed two doublets of doublet at δ 5.02 and 4.90 for H_A and H_B protons respectively. The characteristic signals for NCO and NCN in ^{13}C NMR at 179.7 and 168.7 ppm further identify oxadiazole moiety in **3a**. The structure of **3a** was further supported by the mass spectrum, which showed a molecular ion at *m/z* 222 consistent with the molecular formula $C_{13}H_{22}N_2O$. The detailed spectral data of synthesized compounds **3a–t** are provided in separate Supplementary file.

3. Experimental

Undec-10-enoic and (*Z*)-octadec-9-enoic acids were obtained from Fluka Chemicals. (*9Z,12R*)-12-Hydroxyoctadec-9-enoic (ricinoleic) and (*9R,12Z*)-9-hydroxyoctadec-12-enoic (isoricinoleic) acids were isolated from *Ricinus communis* and *Wrightia tinctoria* seed oils respectively. The concentrate of hydroxy acids were obtained by Gunstone's partitioning[14] of freshly prepared acids and further purified by column chromatography. The esters of fatty acids were prepared by refluxing the fatty acids in methanol in the presence of catalytic amount of sulfuric acid.[15] ^{1}H and ^{13}C NMR spectra were recorded in $CDCl_3$ on a Bruker DRX-400 instrument. The chemical shifts (δ) were measured relative to TMS as an internal standard. Coupling constants (*J*) are expressed in Hz. Mass spectra were obtained on a Jeol SX-102 (FAB) spectrometer, and IR spectra were obtained on Shimadzu 8201 PC FT-IR spectrometer using KBr pellet with absorptions given in cm^{-1}.

3. 1. General Procedure for Synthesis of Amidoximes (2a–e)

Amidoximes were prepared by 2–4 day reflux of solution of the corresponding nitrile with equimolar amounts of hydroxylamine hydrochloride and sodium hydroxide in excess of 10–20% aqueous ethanol. The mixture was then concentrated under vacuum, diluted with cold water and left overnight. The solid that formed was recovered, washed with cold water, dried under vacuum and recrystallized from ethanol (**2a**, mp = 127–128 °C; **2b**, mp = 90–92 °C; **2c**, mp = 110–112 °C; **2d**, mp = 76–78 °C; **2e**, mp = 130–132 °C).[16]

3. 2. General Procedure for the Synthesis of 3,5-disubstituted-1,2,4-oxadiazoles (3a-t) from Long-chain esters (1a-d) with Amidoximes (2a-e) (Method 1)

The 3,5-disubstituted-1,2,4-oxadiazoles were synthesized by modified procedure given by Amarsinghe et al.[17] To the solution of ester **1a–d** (3 mmol) in toluene (5 ml), amidoxime **2a–e** (3.6 mmol) and K_2CO_3 (3.3 mmol) were added. The reaction mixture was stirred for 9–13 hours under reflux conditions and the progress of the reaction was monitored by TLC employing petroleum ether/ethyl acetate (4:1, v/v) as mobile phase. After cooling to room temperature the reaction mixture was diluted with ethyl acetate (25 ml), and washed with brine (10 ml) and water (3 × 10 ml). Organic phase was dried over anhydrous Na_2SO_4, filtered and concentrated. The crude product was further purified by column chromatography (hexane : ethyl acetate, v/v): **3a**, (99:1); **3b**, (98:2); **3c**, (97:3), **3d**, (97:3); **3e**, (99:1); **3f**, (98:2), **3g**, (97:3); **3h**, (97:3); **3i**, (99:1); **3j**, (98:2); **3k**, (97:3); **3l**, (97:3); **3m**, (98:2); **3n**, (97:3); **3o**, (95:5), **3p**, (95:5); **3q**, (99:1); **3r**, (98:2); **3s** (94:6); **3t**, (94:6).

3. 2. General Procedure for the Synthesis of 3,5-disubstituted-1,2,4-oxadiazoles (3a–t) from Long-chain Acid Chlorides (1'a–d) with Amidoximes (2a–e) (Method 2)

Acid chloride **1'a–d** was prepared as reported earlier.[18] In a typical procedure thionyl chloride (10.5 mmol) was added to fatty acid (10 mmol) and heated at 80 °C for 2 hrs to form the corresponding acid chloride **1'a–d**. The progress of the reaction was monitored by TLC and the excess of thionyl chloride was distilled off. Formed acid chloride **1'a–d** (3 mmol) was dissolved in toluene (5 ml), and amidoxime **2a–e** (3.6 mmol) and K_2CO_3 (3.3 mmol) were added. The reaction mixture was stirred for 1.2–1.5 hours under reflux conditions and the progress of the reaction was monitored by TLC employing petroleum ether/ethyl acetate (4:1, v/v) as mobile phase. After cooling to room temperature the reaction mixture was diluted with ethyl acetate (25 ml) washed with brine (10 ml), and water (3 × 10 ml). Organic phase was dried over anhydrous Na_2SO_4, filtered and concentrated. The crude product was further purified by column chromatography (hexane : ethyl acetate, v/v): **3a**, (99:1); **3b**, (98:2); **3c**, (97:3), **3d**, (97:3); **3e**, (99:1); **3f**, (98:2), **3g**, (97:3); **3h**, (97:3); **3i**, (99:1); **3j**, (98:2); **3k**, (97:3); **3l**, (97:3); **3m**, (98:2); **3n**, (97:3); **3o**, (95:5), **3p**, (95:5); **3q**, (99:1); **3r**, (98:2); **3s** (94:6); **3t**, (94:6).

4. Conclusions

The reported methods presents a straightforward procedure for the efficient and facile synthesis of 3,5-disubstituted-1,2,4-oxadiazoles in moderate to excellent yields. The reactions have remarkable synthetic utility and are valuable addition to the synthesis and manipulation of long-chain carboxylic acid derivatives because of the simplicity of one-step reaction.

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6. References

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Povzetek

Prispevek poroča o pripravi vrste novih 3,5-disubstituiranih-1,2,4-oksadiazolov z reakcijo metil alkenoatov oziroma ustreznih kislinskih kloridov z amidoksimi v prisotnosti baze. Strukture pripravljenih spojin so določene s pomočjo IR, masne, ^{1}H in ^{13}C NMR spektroskopije ter elementne analize.