Microwave and Conventional Study of Coumarin-Oxadiazole Adducts and their Anti-Microbial Evaluation

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Abstract

Introduction: Nowadays, researchers are progressively concentrated to generate economical, affordable and also greener synthesis approach for the synthesis of various heterocycles. On look at the beauty of coumarin molecules and oxazoles, it seems to be lead molecules in the anti-microbial area.

Aim: With the target to identify efficient molecules, we studied 2-oxo-2H-chromen-4-yl-2-((5-substituted aryl-1,3,4-oxadiazol-2-yl)thio)acetate derivatives using two synthetic protocol/methods, i.e. conventional synthesis and microwave-based synthesis.

Materials and methods: Two simultaneous methods, i.e. conventional and microwave synthesis have been used for the synthesis of 2-oxo-2H-chromen-4-yl-2-((5-substituted aryl-1,3,4-oxadiazol-2-yl)thio)acetate (6a-l) derivatives. The desired molecules were synthesized by conventional and microwave synthesis and a comparative study was carried out to identify an easy route for industrial applications. The confirmations of the compounds were carried out by spectroscopic techniques such as IR, 1H NMR, 13C NMR, mass spectra and elemental analysis.

Results: All synthesized compounds were evaluated for their in-vitro antibacterial activity against gram-positive bacteria (Staphylococcus aureus, Staphylococcus pyogenes), gram-negative bacteria (Escherichia coli, Pseudomonas aeruginosa), and antifungal activity (Candida albicans, Aspergillus niger).

Conclusions: All conventional synthesis of final coumarin derivatives were completed within 4-6 h. While that of microwave-based reaction took comparatively more reaction time. Surprisingly, the compounds 6f and 6g could not be synthesized by microwave radiation even after 32 minutes of irradiation. As to the medicinal application part, microbial evaluation of synthesized analogues showed that the compounds 6b, 6e, 6d, and 6j were found more potent in comparison to the reference drug.

Keywords
1,3,4-oxadiazole, antimicrobial activity, coumarin, microwave synthesis

INTRODUCTION

Currently, researchers are oriented to generate potent compounds by applying principles of the "Green Chemistry" approaches. It is at the frontiers of this interdisciplinary science and positive side to reduce the environmental issues in global view by developing a technology base that is fundamentally non-toxic to living organisms and the environment. Microwave (MW) irradiation is an efficient technique for the synthesis of heterocyclic compounds using mild reaction conditions and reagent activation in the organic chemistry. It has been a progressive area because of its
capability to reduce reaction time, atom-economy, high
yields, having environmental and economic advantages,
and the simplified work-up processes.2

Many of the heterocyclic compounds have been studied
to date and of these coumarin and oxadiazole have been
found to be the most efficient in enhancing the biological
significance. Literature survey shows that combination of
both these moieties showed extraordinary medicinal im-
portance. Coumarins and several heterocyclic ring con-
taining coumarins are associated with diverse bioactivity
such as anti-inflammatory, antiviral and antitumor, anti-
proliferative, cytotoxic effects against Hep2 cells and many
more.3,4 Oxadiazole have been successfully tested against
several diseases and therefore received special attention
in pharmaceutical chemistry due to its diverse medicinal
potential like antibacterial, antifungal, analgesic, anti-in-
flammatory, antiviral, antitumor, anti-hypertensive, anti-
convulsant, and anti-diabetic properties.5,6 Literature survey
showed that coupling of both these moieties was of extra-
ordinary medicinal importance.7

On the basis of the above discussion, we have reported
an efficient synthesis of 2-oxo-2H-chromen-4-yl-2-((5-
substitutedaryl-1,3,4-oxadiazol-2-yl)thio)acetate (6a-l) de-
rivatives by four step processes and biological application
was carried by their anti-microbial study against various
strains of bacteria and fungi.

MATERIALS AND METHODS

Materials

The required chemicals and solvents for the synthesis were
purchased from Merck Ltd., SD fine chemicals, LOBA
Chemicals and HIMEDIA. Most of the reactions were car-
ried out by standard techniques for exclusion of moisu-
re. Open-end capillary method was used to determine
the melting points of the synthesized derivatives and the
results were reported and were uncorrected. TLC (Thin
Layer Chromatography) was used for reaction monitoring
using ethyl acetate: hexane as mobile phase and visualized
in UV. IR spectra of all compounds were recorded on a
Bruker FT-IR alpha-t (ATR). The 1H NMR and 13C NMR
spectra were recorded on Bruker Spectrophotometer-400
MHz using DMSO-d6 as solvent and TMS as the internal
reference. Mass spectra were recorded on a Schimadzu LC-
MS 2010 spectrometer. Elemental analysis was carried out
by a Perkin-Elmer 2400 CHN analyzer. MW-assisted reac-
tions were carried out in a domestic microwave oven (LG
MC3286BRU) at 180 W.

Method of Synthesis

Procedure for the synthesis of 2-oxo-2H-chromen-4-yl
2-chloroacetate (2).

A solution of coumarin 1 (0.01 mole) in N,N-dimethyl-
formamide (DMF) and triethylamine (TEA) (0.001 mole)
was stirred at room temperature for 10 minutes. Chloro
acetyl chloride (CAC) (0.015 mole) was added in a drop-
wise manner to the reaction mixture at 0-5°C. The reaction
mixture was stirred for 4 h at room temperature and poul-
red onto crushed ice. The solid separated was filtered
and dried using vacuum dryer. The completion of the reaction
was monitored using TLC using n-hexane: ethyl acetate
(7:3) as a mobile phase.

1H NMR (400 MHz, DMSO-d6) δ 7.63 (m, 1H), 7.43
(m, 1H), 7.19 (m, 1H), 5.86 (s, 1H), 4.40 (s, 2H); 13C NMR
(101.1 MHz, DMSO-d6) 164.74, 162.56, 161.94, 152.87,
133.52, 125.68, 124.26, 117.30, 115.47, 99.56, 40.64.

General procedure for the synthesis
of substituted benzohydrazide (4a-l)

A solution of hydrazine hydrate (0.05 mole) in methanol
was added to a solution of substituted methyl benzoate 3a-l
(0.01 mole) in methanol containing round bottom flask
(RBF) and was refluxed for 12 h. Completion of the reacti-
on was monitored out by TLC (mobile phase: hexane: ethyl
acetate). After completion of the reaction, methanol was
distilled off in vacuum and then cooled to room tempera-
ture. It was poured onto crushed ice and separated solid
product was filtered out and washed with cold water. Dried
product was recrystallized using ethanol to afford analyti-
cally pure products.

General procedure for the synthesis
of 5-substitutedphenyl-1,3,4-oxadiazole-2-thiol
(5a-l)

In a 100 ml RBF, ethanolic KOH solution [Ethanol (4 ml):
KOH (0.01 mole)] and various benzohydrazide derivatives
(4a-l) (0.01 mol) were mixed in 100 ml RBF in acetone. To this reaction mixture,
chloroacetate (2) (0.015 mole) and various 5-substituted-
phenyl-1,3,4-oxadiazole-2-thiol (5a-l) (0.01 mol) were
mixed in 100 ml RBF in acetone. To this reaction mixture,
dry K2CO3 powder (0.02 mole) was added to neutralize the
HCl, liberated during the progress of the reaction. The re-
action mixture was stirred at RT for 4-6 h. It was poured
onto crushed ice, filtered, washed with cold water and dried
it. The obtained dried product was crystallized by using
ethanol. The completion of the reaction was confirmed by
using TLC with mobile phase n-hexane: ethyl acetate (7:3).
Studies on Coumarin Adducts

Purification of the final product was carried out by silica gel column chromatography (60-120 mesh) by using ethyl acetate and n-hexane as mobile phase (Fig. 1). All the synthesized newer compounds were completely soluble in polar solvents (mostly in methanol, DMF and DMSO).

All the compounds of the series 6a-1 were synthesized according to the above cited method and characterization was carried out by spectroscopic techniques.

Analytical Data of Representative Compounds

2-oxo-2H-chromen-4-yl 2-((5-phenyl-1,3,4-oxadiazol-2-yl)thio)acetate (6a)

Yield: 81%; mp 284°C; IR (ATR, cm⁻¹): 2862 (-C-H stretching of methylene group), 1736 (>C=O stretching of esteric carbonyl group), 1708 (>C=O stretching of lactone carbonyl group), 1361 (C-N stretching of carbon nitrogen linkage), 1211, 1061 (C-O-C stretching of oxadiazole ring), 1162 (C-O stretching of ester); ¹H NMR (400 MHz, DMSO-d₆, δppm) 8.23 (m, 5H), 7.81 (m, 4H), 7.11 (s, 1H), 4.13 (s, 2H); ¹³C NMR (101 MHz, DMSO-d₆, δppm) 177.60, 170.22, 167.28, 165.15, 161.23, 140.28, 132.61, 130.74, 129.85, 128.35, 127.45, 126.18, 122.87, 116.18, 103.56, 81.33, 36.21; MS: m/z 381 (M⁺); Elemental analysis of C₁₉H₁₂N₂O₅S: Calculated= C, 55.99; H, 3.18; N, 7.36; O, 21.03; S, 8.43 and Experimental= C, 59.97; H, 3.13; N, 7.32; O, 21.01; S, 8.45.

2-oxo-2H-chromen-4-yl 2-((5-(4-nitrophenyl)-1,3,4-oxadiazol-2-yl)thio)acetate (6b)

Yield: 74%; mp 245°C; IR (ATR, cm⁻¹): 2887 (-C-H stretching of methylene group), 1746 (>C=O stretching of esteric carbonyl group), 1704 (>C=O stretching of lactone carbonyl group), 1471, 1313 (C-NO₂ stretching), 1286, 1051 (C-O-C stretching of oxadiazole ring), 1226 (C-O stretching of ester); ¹H NMR (400 MHz, DMSO-d₆, δppm) 7.86 (m, 4H), 7.56 (m, 4H), 7.12 (s, 1H), 4.26 (s, 2H); ¹³C NMR (101 MHz, DMSO-d₆, δppm) 176.62, 173.28, 164.17, 162.63, 160.92, 153.81, 150.15, 147.69, 136.43, 129.64, 127.51, 124.47, 115.20, 113.36, 47.81, 37.10; MS: m/z 426 (M⁺); Elemental analysis of C₁₉H₁₁N₃O₇S: Calculated= C, 53.65; H, 2.61; N, 9.88; O, 26.33; S, 7.54 and Experimental= C, 53.62; H, 2.58; N, 9.75; O, 26.37; S, 7.56.

2-oxo-2H-chromen-4-yl 2-((5-(3-nitrophenyl)-1,3,4-oxadiazol-2-yl)thio)acetate (6c)

Yield: 78%; mp 235°C; IR (ATR, cm⁻¹): 2919 (-C-H stretching of methylene group), 1739 (>C=O stretching esteric carbonyl group), 1702 (>C=O stretching of lactone carbonyl group), 1361 (C-N stretching of carbon nitrogen linkage), 1211, 1061 (C-O-C stretching of oxadiazole ring), 1286 (C-O stretching ester); ¹H NMR (400 MHz, DMSO-d₆, δppm) 8.11 (m, 4H), 7.47 (m, 4H), 7.26 (s, 1H), 4.87 (s, 2H); ¹³C NMR (101 MHz, DMSO-d₆, δppm) 177.18, 174.27, 170.35, 167.21, 162.96, 148.18, 145.32, 142.65, 139.43, 136.21, 132.63, 128.16, 126.92, 124.1, 122.17, 115.20, 113.36, 47.81, 37.10; MS: m/z 426 (M⁺); Elemental analysis of C₁₉H₁₁N₃O₇S: Calculated= C, 53.65; H, 2.61; N, 9.88; O, 26.33; S, 7.54 and Experimental= C, 53.62; H, 2.58; N, 9.75; O, 26.37; S, 7.56.

Figure 1. Reaction scheme. Synthetic pathway of compounds (6a-l).
125.67, 120.23, 115.42, 103.26, 50.15, 38.30; MS: m/z 426 (M^+); Elemental analysis of C_{19}H_{11}N_{3}O_{7}S: Calculated= C, 53.65; H, 2.61; N, 9.88; O, 26.33; S, 7.54 and Found= C, 53.68; H, 2.64; N, 9.91; O, 26.28; S, 7.49.

2-oxo-2H-chromen-4-yl 2-((5-(2-nitrophenyl)-1,3,4-oxadiazol-2-yl)thio)acetate (6d)

Yield: 80%; mp 260°C; IR (ATR, cm^-1): 2965 (-C-H stretching); 1756 (esteric carbonyl group), 1710 (>C=O stretching lactone carbonyl group), 1457, 1321 (C-N stretching nitrogen linkage), 1200, 1071 (C-O stretching oxadiazole ring), 1187 (C-O stretching ester); 1H NMR (400 MHz, DMSO-d_6, δ, ppm) 7.76 (m, 4H), 7.58 (m, 4H), 7.21 (s, 1H), 4.11 (s, 2H); 13C NMR (101 MHz, DMSO-d_6, δ ppm) 7.76 (m, 4H), 7.58 (m, 4H), 7.21 (s, 1H), 4.11 (s, 2H); 13C NMR (101 MHz, DMSO-d_6, δ ppm) 7.18 (s, 1H), 4.84 (s, 2H); 13C NMR (101 MHz, DMSO-d_6, δ ppm) 17.19, 166.75, 164.18, 162.41, 154.18, 153.67, 140.22, 137.19, 132.28, 130.79, 129.15, 127.76, 125.81, 124.53, 123.16, 113.47, 100.86, 50.74, 39.43, 38.61; MS: m/z 449 (M^+); Elemental analysis of C_{19}H_{11}BrN_{3}O_{7}S: Calculated= C, 55.57; H, 2.47; F, 12.71; N, 6.25; O, 17.84; S, 7.15 and Found= C, 55.61; H, 2.44; F, 12.67; N, 6.27; O, 17.89; S, 7.19.

K. Kapadiya et al
Folia Medica I 2021 I Vol. 63 I No. 1

2-oxo-2H-chromen-4-yl 2-((5-(2-nitrophenyl)-1,3,4-oxadiazol-2-yl)thio)acetate (6c)

Yield: 80%; mp 260°C; IR (ATR, cm^-1): 2965 (-C-H stretching); 1756 (esteric carbonyl group), 1710 (>C=O stretching lactone carbonyl group), 1457, 1321 (C-N stretching nitrogen linkage), 1200, 1071 (C-O stretching oxadiazole ring), 1187 (C-O stretching ester); 1H NMR (400 MHz, DMSO-d_6, δ, ppm) 7.76 (m, 4H), 7.58 (m, 4H), 7.21 (s, 1H), 4.11 (s, 2H); 13C NMR (101 MHz, DMSO-d_6, δ ppm) 7.76 (m, 4H), 7.58 (m, 4H), 7.21 (s, 1H), 4.11 (s, 2H); 13C NMR (101 MHz, DMSO-d_6, δ ppm) 7.18 (s, 1H), 4.84 (s, 2H); 13C NMR (101 MHz, DMSO-d_6, δ ppm) 17.19, 166.75, 164.18, 162.41, 154.18, 153.67, 140.22, 137.19, 132.28, 130.79, 129.15, 127.76, 125.81, 124.53, 123.16, 113.47, 100.86, 50.74, 39.43, 38.61; MS: m/z 449 (M^+); Elemental analysis of C_{19}H_{11}BrN_{3}O_{7}S: Calculated= C, 55.57; H, 2.47; F, 12.71; N, 6.25; O, 17.84; S, 7.15 and Found= C, 55.61; H, 2.44; F, 12.67; N, 6.27; O, 17.89; S, 7.19.

2-oxo-2H-chromen-4-yl 2-((5-(2-Chlorophenyl)-1,3,4-oxadiazol-2-yl)thio)acetate (6g)

Yield: 79%; mp 246°C; IR (ATR, cm^-1): 2982 (-C-H stretching methylene group), 1746 (>C=O stretching ester carbonyl group), 1653 (>C=O stretching lactone carbonyl group), 1385 (>C=O stretching carbon nitrogen linkage), 1291, 1073 (C-O-C stretching oxadiazole ring), 1165 (C-O-C stretching ester), 658 (Cl-Cl str); 1H NMR (400 MHz, DMSO-d_6, δ ppm) 7.81 (m, 4H), 7.59 (m, 4H), 7.21 (s, 1H), 4.84 (s, 2H); 13C NMR (101 MHz, DMSO-d_6, δ ppm) 178.19, 166.75, 164.18, 162.41, 154.18, 153.67, 140.22, 137.19, 132.28, 130.79, 129.15, 127.76, 125.81, 124.53, 123.16, 113.47, 100.86, 50.74, 39.43, 38.61; MS: m/z 449 (M^+); Elemental analysis of C_{19}H_{11}ClN_{3}O_{7}S: Calculated= C, 55.01; H, 2.67; Cl, 8.55; N, 6.73; O, 19.28; S, 7.73 and Found= C, 55.23; H, 2.65; Cl, 8.51; N, 6.77; O, 19.31; S, 7.68.

2-oxo-2H-chromen-4-yl 2-((5-(3-Chlorophenyl)-1,3,4-oxadiazol-2-yl)thio)acetate (6j)

Yield: 79%; mp 232°C; IR (ATR, cm^-1): 2876 (-C-H stretching methylene group), 1746 (>C=O stretching ester carbonyl group), 1713 (>C=O stretching lactone carbonyl group), 1364 (C-N stretching carbon nitrogen linkage), 1291, 1068 (C-O-C stretching oxadiazole ring), 1203 (C-O-C stretching ester), 1016 (C-F str); 1H NMR (400 MHz, DMSO-d_6, δ ppm) 7.62 (m, 4H), 7.25 (s, 1H), 4.63 (s, 2H); 13C NMR (101 MHz, DMSO-d_6, δ ppm) 177.63, 165.54, 163.13, 162.41, 154.18, 153.67, 140.22, 137.19, 132.28, 130.79, 129.15, 127.76, 125.81, 124.53, 123.16, 113.47, 100.86, 50.74, 39.43, 38.61; MS: m/z 449 (M^+); Elemental analysis of C_{19}H_{11}ClN_{3}O_{7}S: Calculated= C, 55.01; H, 2.67; Cl, 8.55; N, 6.73; O, 19.28; S, 7.73 and Found= C, 55.23; H, 2.65; Cl, 8.51; N, 6.77; O, 19.31; S, 7.68.
Antimicrobial screening methodology

The newly synthesized entities (6a-l) were screened for their antimicrobial assay against a broad panel of gram-positive bacteria i.e. S. aureus (ATCC No. 25923), E. faecalis (ATCC No. 29212) and gram-negative bacteria i.e. E. coli (ATCC No. 25922), P aeruginosa (ATCC No. 27853), and fungi C. albicans (ATCC No. 10231), A. niger (ATCC No. 1015). Antifungal and antibacterial evaluations were carried out by micro dilution/broth titer method. The stock solution (DMSO: 1000 μg/ml) for each compound was prepared and antimicrobial assay was carried out by serial dilution and preparing the sets consecutively from 1000, 500, 200, 100, 50, 25 and 12.5 μg ml⁻¹. The tubes along with the control were then kept for incubation at 37°C for 24 h. Suspending bacteria were further inoculated on an appropriate media and growth was noted after 48 h. The obtained results (MIC) in μg/ml was noted by observing the highest dilutions (low turbidity) were recorded and compared with the MIC value of standard drugs using ampicillin for antibacterial activity and griseofulvin for antifungal activity.

RESULTS AND DISCUSSION

Chemistry: synthetic and microwave based approach

The key intermediate 2-oxo-2H-chromen-4-yl-2-chloroacetate (2) was synthesized in excellent yields by condensation of 4-hydroxy-2H-chromen-2-one and chloroacetyl chloride under basic condition by stirring at RT. To introduce the oxadiazole ring to coumarin moiety, intermediate 5a-l was accomplished by hydrazide formation of molecules 6a-l followed by reaction with CS₂ in acidic condition under refluxed for 14 h. Novel molecules 6a-l were synthesized by coupling of previously prepared intermediate 2 and 5a-l using dry K₂CO₃ as a catalyst and acetone as a solvent in handsone yields (around 80%) as shown in Fig. 1.

To make the process economical as well as ecofriendly, we have tried green chemistry approach for the synthesis of compounds 6a-l by microwave irradiation method. Table 1 summarized the comparison study between conventional and microwave processes.

The desired molecules (6a-l) were synthesized from intermediate 2 and 5a-l with yields ranging from 74% to 84% when synthesized by conventional method and 0-70% when synthesized using microwave irradiation. Literature study shows that microwave-assisted synthesis led to improved yields and less reaction time, but in our case reverse statistics were observed. Comparative analysis of percentage yields and reaction time for all 6a-l derivatives by both methods are summarized in Table 1.
conventional method and microwave-assisted method was carried out to find out if microwave-assisted synthesis of coumarin derivatives adds any advantage or not.

All conventional synthesis of final coumarin derivatives were completed within 4-6 h, while that of microwave based reaction took comparatively more reaction time. Table 1 shows that compounds 6f and 6g could not be synthesized by microwave radiation even after 32 minutes of irradiation.

**Spectroscopic analysis**

Successful formation of our key products coumarin derivatives 6a-l has been confirmed by spectroscopic analysis such as $^1$H NMR, $^{13}$C NMR and mass analysis, which are further supported by elemental analysis and IR spectral studies.

In the IR spectrum, the structure of 6a-l showed a characteristic absorption band at ~1755 cm$^{-1}$ due to esteric carbonyl structure and for lactone ring, it was found at ~1740 cm$^{-1}$. Moreover, the absence of primary amine stretching value at 3300 cm$^{-1}$ show that the desired adduct 5a-l has been formed. Disappearance of the $-S-H$ stretching frequency and appearance of C–S value indicated that C–S–C linkage was formed between coumarin and oxadiazole ring.

The $^1$H NMR spectral data of 6a-l showed a characteristic value at ~4.0 δppm due to presence of methylene group near to esteric oxygen atom. Compounds 6j, 6k and 6l showed singlets at ~3.5 δppm, which confirms the presence of a methyl group. Remaining aromatic and substituents protons were in good agreements with theoretical values.

The $^{13}$C NMR spectra helped us to identify the formation of the final adducts. The characteristic value at ~35 δppm showed the presence of methylene group and C-3 (carbon number 3) of coumarin ring exhibited peak at ~99 δppm. The aromatic ring carbon and heterocyclic ring carbons were in decent covenants with the theoretical values.

**Biological evaluation**

**Antibacterial screening**

All the newly synthesized moiety (6a-l) were evaluated for their in vitro antibacterial activity against gram-positive bacteria (*Staphylococcus aureus* and *Staphylococcus pyogenes*) and gram-negative bacteria (*Escherichia coli* and *Pseudomonas aeruginosa*) by conventional broth microdilution method using ampicillin as a standard drug for antibacterial activity at different concentrations of 1000, 500, 200, 100, 50, 25 and 12.5 µg ml$^{-1}$ as shown in Table 2. Compound 6b (-4-NO$_2$-C$_6$H$_4$) has excellent activity against *E. coli* and *S. aureus*. It is noteworthy that compound 6b (-4-NO$_2$-C$_6$H$_4$) showed the greatest inhibition at MIC= 12.5 µg ml$^{-1}$, while compound 6e (-4-F-C$_6$H$_4$) showed inhibition at MIC= 12.5 µg ml$^{-1}$ against *P. aeruginosa* and *S. pyogenes*. These data revealed that compound 6e (-4-F-C$_6$H$_4$) was highly active against both organisms. Compounds 6b (-4-NO$_2$-C$_6$H$_4$) and 6e (-4-F-C$_6$H$_4$) showed very good activity at MIC= 50 µg ml$^{-1}$. Compound 6e (-4-F-C$_6$H$_4$) displayed very good activity against *P. aeruginosa* while compound 6b (-4-NO$_2$-C$_6$H$_4$) showed

**Table 2.** In vitro results of antibacterial and antifungal screening of compounds 6a-l

<table>
<thead>
<tr>
<th>No.</th>
<th>-R</th>
<th>Minimum inhibitory concentration (MIC) in µg ml$^{-1}$</th>
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<tr>
<td></td>
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<td>Bacteria</td>
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<tr>
<td>6a</td>
<td>-H</td>
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</tr>
<tr>
<td>6b</td>
<td>-4-NO$_2$</td>
<td>12.5</td>
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<tr>
<td>6c</td>
<td>-3-NO$_2$</td>
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<td>-2-NO$_2$</td>
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<td>6e</td>
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<td>-4-Cl</td>
<td>100</td>
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<tr>
<td>6g</td>
<td>-3-Cl</td>
<td>125</td>
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<td>250</td>
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<td>6i</td>
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<td>500</td>
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<td>6l</td>
<td>-2-CH$_3$</td>
<td>250</td>
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<tr>
<td>Ampicillin</td>
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<td>100</td>
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<tr>
<td>Griseofulvin</td>
<td></td>
<td>-</td>
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</table>

E.c.: *Escherichia coli* MTCC 443; Pa.: *Pseudomonas aeruginosa* MTCC 1688; S.a.: *Staphylococcus aureus* MTCC 96; S.p.: *Staphylococcus pyogenes* MTCC 442; C.a.: *Candida albicans* MTCC 227; A.n.: *Aspergillus niger* MTCC 282.
very good activity against *E. coli*. Moreover, compound 6d (-2-NO2-C6H4) exhibited very good activity against *S. aureus*. Compounds 6c (-3-NO2-C6H4) and 6f (-4-Cl-C6H4) displayed good activity against *E. coli* and *S. aureus* while compound 6i (-4-Br-C6H4) showed good activity against *P. aeruginosa* and *S. aureus* at MIC=100 µg ml\(^{-1}\). The remaining compounds of the series possessed feeble antibacterial activity. On the other hand, the presence of similar functional groups at the para position resulted in minor increase in antibacterial activity as compared to 6b (-4-NO2-C6H4) and 6e (-4-F-C6H4).

**Antifungal screening**

Minimum inhibition concentration (MIC) values of antifungal activity were observed against *Candida albicans*, and *Aspergillus niger* by conventional broth micro dilution method in Table 2 using griseofulvin as a standard drug. Antifungal activity displayed that compound 6j (-4-CH3-C6H4) showed very good activity against *A. niger* at 12.5 µg ml\(^{-1}\) MIC. It was confirmed in the above table that compound 6g (-3-Cl-C6H4) exhibited slightly reduced activity against *C. albicans*, while compound 6c (-3-NO2-C6H4) possessed good activity against *A. niger* and *C. albicans*, respectively. A couple of molecules i.e. 6d (-2-NO2-C6H4) and 6j (-4-CH3-C6H4) showed excellent activity against *C. albicans* and *A. niger* with fourfold greater MIC (12.5-50 µg ml\(^{-1}\)) than the reference drug. The remaining compounds of the series exhibited feeble antifungal activity.

**CONCLUSIONS**

In this short communication, we have described the comparative study for the synthesis of 2-oxo-2H-chromen-4-yl 2-((5-substitutedaryl-1,3,4-oxadiazol-2-yl)thio)acetate (6a-l) derivatives using conventional and microwave approaches. All the synthesized compounds were screened for their anti-microbial and anti-fungal study. It was concluded that electron withdrawing group containing scaffolds i.e. 6b, 6c, 6d, and 6j showed the best response when compared to the reference drugs, while 6d and 6j molecules exhibited extraordinary anti-fungal activity.

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**Conflict of Interest**

The authors declare that there is no conflict of interest.

**Author contribution**

Laboratory synthesis was carried out by Piyush Dholairya and the remaining biological work and writing were carried out by Khushal Kapadiya.

**REFERENCES**

Микроволновое и традиционное исследование аддуктов кумарин-оксадиазол и их антимикробная оценка

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Резюме

Введение: В настоящее время учёные продолжают сосредоточиваться на создании экономичного, доступного и экологически чистого синтеза различных гетероциклов. В форме молекул кумарина и оксадиазолов молекулы свинца, по-видимому, находятся в антимикробной области.

Цель: Для установления эффективных молекул мы протестировали производные 2-оксо-2H-хромен-4-ил-2 - ((5-арилзамещенный-1,3,4-оксадиазол-2-ил) тио) ацетата с использованием двух синтетических протоколов / методов, т.е. традиционный синтез и синтез на основе микроволнового излучения.

Материалы и методы: Два одновременных метода – т.е. традиционный синтез и синтез на основе микроволнового излучения были использованы для синтеза (6a-l) производного 2-оксо-2H-хромен-4-ил-2 - ((5-арилзамещенный-1,3,4-оксадиазол-2-ил) тио) ацетат. Желаемые молекулы были синтезированы с помощью традиционного и микроволнового синтеза, и было проведено сравнительное исследование, чтобы определить простой путь для промышленного применения. Подтверждение ингредиентов проводили с помощью спектроскопических методов, таких как ИК, 1H ЯМР, 13С ЯМР, масс-спектральный и элементный анализ.

Результаты: Все синтезированные ингредиенты были оценены на предмет антибактериальной активности in vitro против грамположительных бактерий (Staphylococcus aureus, Staphylococcus pyogenes), грамотрицательных бактерий (Escherichia coli, Pseudomonas aeruginosa) и противогрибковой активности (Candida albicans, Aspergillus niger)

Заключение: Все традиционные синтезы конечных производных кумарина были завершены в течение 4-6 часов, в то время как синтез с использованием микроволн длился относительно долго. Удивительно, но ингредиенты 6f и 6g не могут быть синтезированы микроволновым излучением даже после 32 минут облучения. Что касается части введения лекарственного средства, микробиологическая оценка синтезированных аналогов показала, что ингредиенты 6b, 6e, 6d и 6j были более эффективными по сравнению с референтным лекарством.

Ключевые слова
1,3,4-оксадиазол, антимикробное действие, кумарин, микроволновый синтез