

Design, Synthesis and Biological evaluation of novel mixed ligand complexes containing oxovanadium

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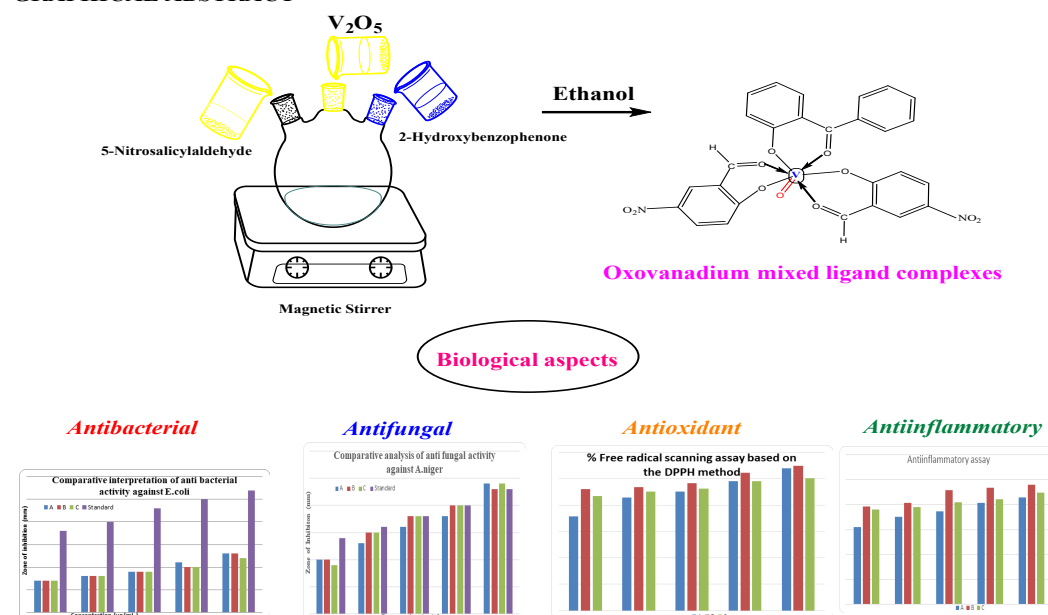
ABSTRACT

Oxovanadium complexes have been synthesized by the reaction between V_2O_5 and bidentate ligands such as 5-nitrosalicylaldehyde (Primary ligand) and 2-hydroxybenzophenone [complex A], 1-phenyl-1,3-butanedione [complex B], and 5-chlorosalicylaldehyde [complex C] (Secondary ligand) in 1:2:1 molar ratios respectively. The synthesized complexes were analyzed for antibacterial activity against *Bacillus subtilis* and *Escherichia coli*, antifungal activity against *Aspergillus niger* and *Penicillium chrysogenum*. Antioxidant and anti-inflammatory activities were also analyzed. All three complexes showed moderate antibacterial activity. Compounds A and C showed more antifungal activity (IZ = 24 mm; AI = 1.04 at 100 μ g/mL) contrary to the reference drug (IZ = 23 mm) against *Aspergillus Niger*. Compound A showed the strongest antifungal activity against *Penicillium chrysogenum* (AI > 1) at all concentrations, even at lower doses (IZ = 15 mm at 20 μ g/mL; AI = 1.15) than the standard drug. Compound B exhibited highest antioxidant activity ($54.89 \pm 0.12\%$ inhibition at 100 μ g/mL). Compound B also showed stronger anti-inflammatory potential relative to other samples. The study accentuates the significance of mixed-ligand coordination in modifying the structural, electrical, and biological assets of oxovanadium complexes, suggesting potential applications in pharmaceutical and bioinorganic chemistry.

Keywords: Oxovanadium complexes, mixed ligand, Coordination chemistry, pharmaceutical, bioinorganic.

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GRAPHICAL ABSTRACT



1. INTRODUCTION

Transition metal coordination chemistry is still an actively studied topic due to its fundamental importance in inorganic synthesis, structural chemistry, catalysis, and medical applications¹. Vanadium is one of the transition metals

that has been receiving the most attention because of its numerous oxidation states (–I to +V), flexible coordination geometries, and substantial biological importance². Vanadium complexes have demonstrated promising applications in catalysis, material science, and medicinal chemistry,

particularly in antidiabetic, antimicrobial, and anticancer research³. The ability of vanadium to coordinate readily with oxygen- and nitrogen-donor ligands supports its application as an ideal candidate for designing mixed ligand systems with enhanced physicochemical and biological properties⁴. Mixed ligand complexes are widely studied because they often exhibit synergistic effects arising from the presence of two different donor ligands in the same coordination shell⁵. Such systems can modulate electronic distribution, geometry, stability, and reactivity more effectively than single-ligand complexes⁶.

In this context, salicylaldehyde derivatives and β -diketones represent a well-known group of chelating ligands due to their strong coordinating ability via phenolic oxygen and carbonyl groups.⁷⁻⁸ Transition metal complexes with mixed ligands are widely studied for their ability to generate materials exhibiting magnetic exchange, conductivity, photoluminescence, and nonlinear optical behavior⁹⁻¹². The biological significance of mixed-ligand complexes is well documented due to their higher effectiveness than their corresponding free ligands.¹³⁻¹⁴ Mixed ligand complexes execute a vital role in biological activities like Antibacterial, Antioxidant, Anticancer, Antidiabetic, Anti-tuberculosis, antitumor, antiproliferative, Antifungal Antiparasitic, Antiviral, Antihyperglycemic and Anti-inflammatory¹⁵⁻²¹.

The production of novel mixed ligand vanadium complexes utilizing V_2O_5 as the metal precursor is the primary objective of this study. The primary ligand selected is 5-nitrosalicylaldehyde (PL), a substituted salicylaldehyde containing both phenolic -OH and aldehydic functional groups, which facilitates chelation through oxygen donor atoms. The nitro substituent further influences electron density and coordination behavior, enhancing metal-ligand interaction strength. The primary ligand is employed in two molar equivalents in each complex, ensuring the formation of stable chelated frameworks around the vanadium center. Three different secondary ligands (SL) are incorporated to generate distinct mixed ligand complexes, 2-Hydroxybenzophenone, 1-Phenyl-1,3-butanedione, 5-Chlorosalicylaldehyde. In this article, antimicrobial, antioxidant and anti-inflammatory activities were investigated to explore the ability of mixed-ligand coordination on the biological attributes of oxovanadium complexes. FT-IR, UV-Visible, ¹H NMR, XRD, XPS techniques and Micro elemental analysis were used to examine the generated complexes which are discussed in previous work.

2. EXPERIMENTAL

2.1 Materials

5-nitrosalicylaldehyde (TCI), 2-hydroxybenzophenone (TCI), 1-phenyl-1,3-butanedione (TCI), and 5-chlorosalicylaldehyde (TCI) have been purified by recrystallization with help of hot ethanol. 5-chlorosalicylaldehyde, 5-nitrosalicylaldehyde and n-butanol was filtered by distillation before its utilization. As given, V_2O_5 of A.R. grade was used.

2.2 Synthesis

Synthesis of complexes A

Synthesis of novel ligand complex of V_2O_5 with 5-Nitrosalicylaldehyde and 2-hydroxybenzophenone

To a ethanolic solution of V_2O_5 (0.55 mmol, 0.10g. in 10ml), a ethanolic solution of 5-nitrosalicylaldehyde (1.197 mmol, 0.20g. in 10 ml) and 2-hydroxybenzophenone (0.555 mmol, 0.11g. in 10 ml) were added with continuous stirring. With constant mixing, a 5% aqueous solution of sodium hydroxide was slowly added dropwise to elevate the pH level of the assortment to about 7.5. For six hours, this procedure was performed. Next, the reaction mixture was maintained under reflux for five hours and was then left at room temperature for twelve hours. In order to eliminate stickiness, the settling solid was purified, cleaned with ethyl alcohol and then ether, and dried appropriately under low pressure.

Synthesis of complexes B

Synthesis of novel ligand complex of V_2O_5 with 5-Nitrosalicylaldehyde and 1-phenyl-1,3-butanedione

Ethanolic solutions of V_2O_5 (0.55 mmol, 0.10g in 10 ml), 5-nitrosalicylaldehyde (1.197 mmol, 0.20g in 10 ml), and 2-hydroxybenzophenone (0.555 mmol, 0.11g in 10 ml) were added while stirring continuously. To raise the combination's pH to around 7.5, a 5% aqueous solution of sodium hydroxide was gradually added dropwise while the liquid was continuously mixed. This process was carried out for six hours. The reaction mixture was then retained under reflux for five hours before being allowed to sit at room temperature for twelve hours. The settling solid was clean, washed with ethyl alcohol and then ether, and dried properly under moderate pressure to remove stickiness.

Synthesis of complexes C

Synthesis of novel ligand complex of V_2O_5 with 5-Nitrosalicylaldehyde and 5-chlorosalicylaldehyde

V_2O_5 (0.55 mmol, 0.10 g in 10 ml), 5-nitrosalicylaldehyde (1.197 mmol, 0.20 g in 10 ml), and 2-hydroxybenzophenone (0.555 mmol, 0.11 g in 10 ml) were added to an ethanolic solution while stirring continuously. To raise the mixture's pH to around 7.5, a 5% aqueous solution of sodium hydroxide was gradually added dropwise while continuing to mix. This treatment was carried out for six hours. The reaction mixture was then kept under

reflux for five hours before being allowed to sit at room temperature for twelve hours. The settling solid was clean, washed with ethyl alcohol and then ether, and dried properly under moderate pressure to get rid of stickiness.

2.3 Antibacterial activity

Nutrient agar was used for antibacterial research, and the agar well diffusion methodology was used to measure antimicrobial activity in vitro²². Dimethyl sulphoxide (DMSO) was used as diluent for different samples and compounds were prepared at 4 different concentrations. Sterilized petri plates with nutrient agar (NA) medium were inoculated with test microorganisms. The inoculum was spread out using a spreader and let to stand for 30 minutes. The seeded agar plates were constructed with 6 mm diameter wells. Similar amounts of the standard medication were also added to another petri dish. The reference drug (30 µl in each well) and varied concentrations of all the samples were mixed to the predetermined wells of seeded plates. For a whole day, the plates were incubated at 37°C. The inhibition zones (IZ) that emerged around each well were assessed in order to identify antibacterial activity of the test chemicals. The zone diameters were compared with those produced by the standard antibiotic, erythromycin, to assess their relative efficacy.

By comparing the action of the samples with the conventional antibiotic medication, the Activity Index was derived. The activity index was computed using the following formula-

$$\text{Activity Index (AI)} = \frac{\text{Sample Inhibition zone}}{\text{Standard Inhibition zone}}$$

2.4 Antifungal activity

For the in-vitro antimicrobial test, a standard microbiological procedure called the Agar Well Diffusion method was carried out. The test uses Potato Dextrose agar to test for antifungal activity. Four discrete volumes of the individual samples were prepared (25 µl, 50 µl, 75 µl, and 100 µl) for each chemical. Test microorganisms were placed into sterile petri plates in potato dextrose agar (NA) medium. The inoculum was spread throughout using a spreader and let to stand for 30 minutes. Six-millimeter diameter wells were taken in the sowed agar plates. A standard drug was also applied at comparable concentrations in a separate Petri plate. Changed concentrations of the test samples and the standard drug were loaded into pre-punched wells in the inoculated agar plates. The plates were subsequently incubated at 37 °C for 72 hours. The inhibition zone (IZ) surrounding each well was analyzed to gauge antibacterial activity, and the test substance zone widths were compared to those of the common antibiotic, ketoconazole²³.

The Activity Index (AI) was calculated by comparing the activity of sample to that of the standard antibiotic drug. The activity index was calculated using the formula below:

$$\text{AI} = \frac{\text{Sample Inhibition zone}}{\text{Standard Inhibition zone}}$$

2.5 Antioxidant potential

2.5.1 DPPH assay Method

The 1,1-diphenyl 2-picryl-hydrazil (DPPH) technique was used to assess the extracted material's capacity to scavenge DPPH radicals²⁴. A 100 µl sample was mixed with 4.2 ml of a 0.1 mM DPPH alcoholic solution. The combination was then utilized and allowed to stand in the dark for approximately an hour. The OD of alcohol has been evaluated at 515 nm using it as a blank.

The ratio = $(\text{Ab}_{\text{control}} - \text{Ab}_{\text{sample}} / \text{Ab}_{\text{control}}) \times 100$ was applied to compute the radical scavenging action. The absorbance of the DPPH solution is demonstrated by $\text{Ab}_{\text{control}}$, while the absorbance of the DPPH solution with sample is represented by $\text{Ab}_{\text{sample}}$.

IC₅₀ values were calculated from concentration-response plots (linear) and defined as the concentration required inhibiting 50% of DPPH radicals²⁵.

2.6 Testing of anti-inflammatory efficacy in vitro

2.6.1 Heat-induced bovine serum albumin denaturation analysis suppression

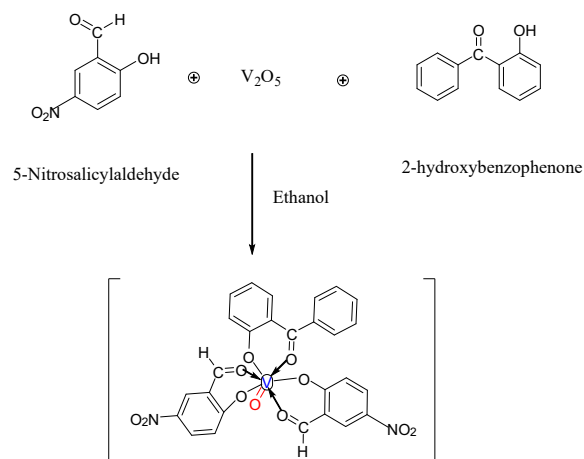
With a few modest adjustments, the impact of complex on the heat-induced bovine serum albumin (BSA) denaturation analysis was done. Phosphate buffered saline (PBS, pH 6.2) and 1% w/v BSA were added to the reaction solutions at varied concentrations (100–1000 µg/mL), with PBS serving as the control. Similar amounts of paracetamol were utilized as the reference. The temperature was elevated to retain the samples at 70°C for 5 minutes after the reaction solutions underwent incubation at 37°C for twenty minutes. After cooling, turbidity has been determined at 650 nm using a UV-visible spectrophotometer. 100% protein denaturation is represented by the control²⁶. The resulting formula was used to determine the % inhibition of BSA denaturation:

$$\% \text{ inhibition of BSA denaturation} = 100 - (\text{Ab}_{\text{Control}} - \text{Ab}_{\text{test}}) / \text{Ab}_{\text{Control}} \times 100$$

3. RESULTS AND DISCUSSION

3.1 Scheme of mixed ligand complexes [VO(NO₂sal)₂(hbp)] (A)

The reactions of V₂O₅ with 5-Nitrosalicylaldehyde and β-diketones such as 2-hydroxybenzophenone, 1-phenyl-1,3-butanedione and salicylaldehyde derivative, 5-chlorosalicylaldehyde in 1:2:1 molar proportions result in the formation of mixed ligand complexes of vanadium. (Scheme-1)



Scheme 1: Synthesis of novel mixed ligand complexes A of Vanadium with 5-Nitrosalicylaldehyde and 2-hydroxybenzophenone

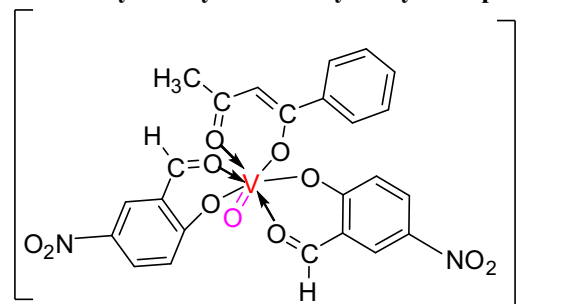


Figure 1: Structure of complexes [VO(NO₂sal)₂(bzac)] (B)

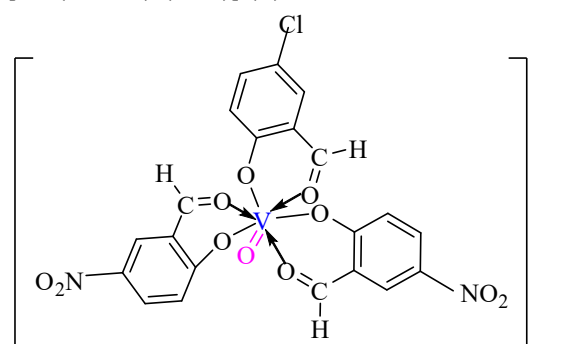


Figure 2: Structure of complexes [VO(NO₂sal)₂(5-Clal)] (C)

For these mixed ligand complexes, deformed octahedral geometry has been suggested, which results in yellow-coloured solids. The determined values for the related complexes are in good accordance with proportion of C, H, and V. The complexes display a propensity to break down when heated to extreme temperatures. These are entirely soluble in DMF and DMSO, but very weakly soluble in nitrobenzene, chloroform, benzene, carbon tetrachloride. **Table-1** shows the microanalytical data of the resultant complexes.

Table 1: Analytical and Spectroscopic Characterization of Mixed-Ligand Complexes

S.N o.	Complex	Color Yield %	Molecular Formula Molecular Weight	Analysis%Found (calculated)			Meltin g point
				V	C	O	
A. 1	[VO(NO ₂ sal)(hbp)]	Yellow 52.68	C ₂₁ H ₁₇ O ₁₁ N ₂ V 596.37 g/mol	8.47 (8.54)	54.27 (54.36)	29.30 (29.51)	310
B. 2	[VO(NO ₂ sal) ₂ (bzac)]	Yellow 46.12	C ₃₃ H ₁₇ O ₁₁ N ₂ V 560.34 g/mol	8.97 (9.09)	51.32 (51.46)	31.12 (31.41)	321
C.	[VO(NO ₂ sal) ₂ (5-Clal)]	Yellow 59.56	C ₂₁ H ₁₂ O ₁₁ N ₂ Cl V 599.17 g/mol	8.61 (8.50)	41.93 (42.09)	29.67 (29.37)	318

3.2 BIOLOGICAL ELUCIDATION

3.2.1 Antibacterial Activity

Utilizing the agar well diffusion method, the antibacterial prospect of the generated compounds was examined against *Bacillus subtilis* and *Escherichia coli* using Azithromycin as the standard reference²⁷⁻²⁹.

Activity against *E. coli*

All compounds have shown moderate antibacterial activity with gradual increase in inhibition zone (IZ) with increasing concentration (20-100 µg/mL). Compound A exhibited relatively better activity at higher concentrations (IZ = 13 mm at 100 µg/mL; AI = 0.48) followed by compounds B and C. However, the activity was lower than the standard drug (IZ = 27 mm at 100 µg/mL).

Activity against *Bacillus subtilis*

An analogous trend was observed against *Bacillus subtilis*. The inhibition zones were increased with concentration in dose dependent manner. Compounds A and C showed similar activities at higher concentrations (IZ = 13 mm at 100 µg/mL; AI = 0.48), while compound B exhibited a slightly lower efficacy (IZ = 12 mm; AI = 0.44). However, all compounds were substantially less potent than the standard (IZ = 27 mm).

Table – 2 summarizes the antibacterial potential of the complexes combating *Bacillus subtilis* and *E. coli* and at different concentrations. According to the results, the zone of inhibition progressively grows as concentration increases, demonstrating stronger antibacterial activity at higher dosages.

Among the tested compounds, compounds A and C exhibited comparatively better activity, although all compounds showed lower efficacy than the standard drug Azithromycin

Table 2: Antibacterial activity of synthesized complexes

Microor ganism	Comp ound	20 µg/mL (IZ/AI)	40 µg/mL	60 µg/mL	80 µg/mL	100 µg/mL (IZ/AI)
		µg/mL	µg/mL	µg/mL	µg/mL	µg/mL

Microorganism	Compound	20 µg/ mL (IZ/ AI)	40 µg/ mL	60 µg/ mL	80 µg/ mL	100 µg/ mL
<i>E. coli</i>	A	7 / 0.38	8 / 0.4 0	9 / 0.3 9	11 / 0.4 4	13 / 0.4 8
	B	7 / 0.38	8 / 0.4 0	9 / 0.3 9	10 / 0.4 0	13 / 0.4 8
	C	7 / 0.38	8 / 0.4 0	9 / 0.3 9	10 / 0.4 0	12 / 0.4 4
	Standard	18	20	23	25	27
<i>B. subtilis</i>	A	7 / 0.36	8 / 0.4 0	9 / 0.4 0	11 / 0.4 2	13 / 0.4 8
	B	7 / 0.36	8 / 0.4 0	9 / 0.4 0	10 / 0.3 8	12 / 0.4 4
	C	7 / 0.36	8 / 0.4 0	9 / 0.4 0	11 / 0.4 2	13 / 0.4 8
	Standard	19	20	22	26	27

Activity Index (AI) was computed using the following formula:

AI = Sample Inhibition zone / Standard Inhibition zone
The contrastive bar graph illustrates the antibacterial activity of synthesized complexes A, B, and C towards *E. coli* at varying concentrations (20–100 µg/mL). Dose sensitive increase in the zone of inhibition was detected, confirming a concentration-dependent antibacterial effect. Among the tested compounds, compounds A and B displayed relatively higher activity at 100 µg/mL, whereas compound C exhibited slightly lower inhibition. However, all

synthesized compounds reflected lower antibacterial activity than the standard drug Azithromycin. The graphical representation confirms the moderate antibacterial potential of the synthesized derivatives against *E. coli* (Figure 3).

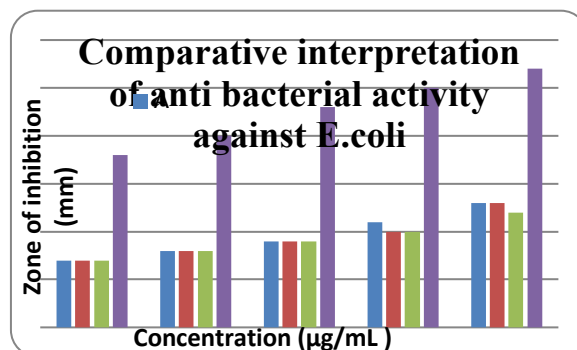


Figure 3: Bar graph representing the antibacterial efficacy of complexes against *E. coli* at different concentrations (20–100 µg/mL)

The bar graph (Figure 4) denotes the antibacterial activity of synthesized compounds A, B, and C against *Bacillus subtilis* at varying amounts (20–100 µg/mL). The zone of inhibition progressively grew with increasing concentration, indicating a positive correlation between concentration and antibacterial properties. Compounds A and C demonstrated greater action at higher doses, while compound B displayed somewhat less inhibition. However, compared to the widely used drug azithromycin, all developed compounds exhibited lower antibacterial effectiveness. The generated compounds show a moderate degree of antibacterial activity against *Bacillus subtilis*, according to the graphical data.

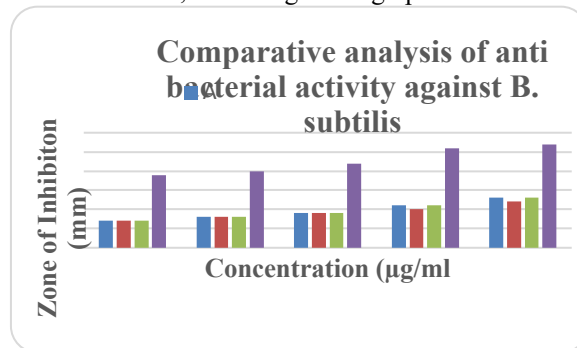


Figure 4: Bar graph showing antibacterial activity of complexes against *Bacillus subtilis*.

3.2.2 Antifungal Activity

The potential of antifungals of the complexes against *Aspergillus niger* and *Penicillium chrysogenum* was evaluated using ketoconazole as a reference³⁰⁻³¹.

Activity of *Aspergillus niger*

The tested compounds exhibited significant antifungal action, particularly at higher doses. Compounds A and C had more effectively action (IZ

= 24 mm; AI = 1.04 at 100 µg/mL) contrary to the reference drug (IZ = 23 mm). Compound B had substantial action at many concentrations with an AI of 1.00, revealing comparable efficacy to the standard.

Activity of *Penicillium chrysogenum*:

There were significant variations in the compound's levels of activity. Compound A showed the strongest antifungal activity (AI > 1) at all concentrations, even at lower doses (IZ = 15 mm at 20 µg/mL; AI = 1.15) than the standard drug. For compounds B and C, however, the lower zones of inhibition and activity level measurements showed modest activity.

Table 3 summarizes the generated compounds' antifungal efficacy against *Aspergillus niger* and *Penicillium chrysogenum* at different dosages. The findings showed that the zone of inhibition progressively grew with concentration, suggesting greater antifungal activity at higher doses. Compound A showed somewhat stronger antifungal activity among the investigated compounds, particularly against *Penicillium chrysogenum*, while compound Band C demonstrated substantial action against *Aspergillus niger*. Certain substances exhibited effects akin to those of the popular drug ketoconazole at higher dosages.

Table 3: Antifungal activity of synthesized complexes

Microorganism	Compound	20 µg/ mL (IZ/ AI)	40 µg/ mL	60 µg/ mL	80 µg/ mL	100 µg/ mL
<i>A. niger</i>	A	10 / 0.71	13 / 0.8	16 / 0.8	18 / 0.9	24 / 1.0
	B	10 / 0.71	15 / 0.9	18 / 1.0	20 / 1.0	23 / 1.0
	C	9 / 0.64	15 / 0.9	18 / 1.0	20 / 1.0	24 / 1.0
	Standard	14	16	18	20	23
<i>P. chrysogenum</i>	A	15 / 1.15	18 / 1.2	20 / 1.1	21 / 1.0	24 / 1.0
	B	7 /	9 / 0.6	11 / 0.6	13 / 0.6	16 / 0.6

Microorganism	Compound	20 µg/ mL (IZ/ AI)	40 µg/ mL	60 µg/ mL	80 µg/ mL	100 µg/ mL
		0.53	0	1	5	9
	C	8 / 0.61	9 / 0.6	13 / 0.7	15 / 0.7	18 / 0.7
			0	2	5	8
	Standard	13	15	18	20	23

The comparative bar graph (**Figure 5**) shows analysis of antifungal activity against *A. niger* at different concentrations. A dose-dependent antifungal effect was demonstrated by the zone of inhibition increasing gradually with concentration. At higher concentrations, compounds A and C showed relatively stronger efficacy, resulting in zones of inhibition that were either slightly larger or comparable to those of the conventional medication ketoconazole. Significant antifungal activity was likewise shown by compound B at all tested doses. The produced compounds appear to have promising antifungal activity against *A. niger*, according to the graphical analysis.

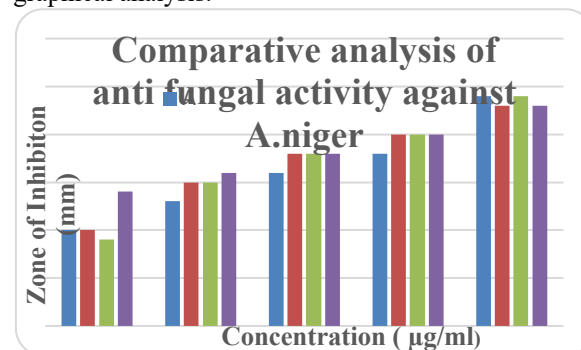


Figure 5: A bar graph showing antifungal efficacy against *A. niger*

The antifungal activity of synthetic compounds A, B, and C against *Penicillium chrysogenum* at different doses is shown in the bar graph (**Figure 6**). Of the substances examined, compound A demonstrated the highest antifungal activity at all concentrations and demonstrated greater inhibition than the standard drug Ketoconazole at higher concentrations. A gradual rise in the inhibition zone was observed with increasing concentration, indicating enhanced antifungal effectiveness at higher doses. With relatively smaller inhibition zones, compounds B and C showed modest antifungal efficacy. The image

illustrates compound A's powerful antifungal ability against *Penicillium chrysogenum*.

The bar graph (**Figure 6**) depicts the antifungal activity of synthesized compounds A, B, and C against *Penicillium chrysogenum* at various concentrations. A gradual rise in the inhibition zone was observed with increasing concentration, indicating enhanced antifungal effectiveness at higher doses among the tested compounds, compound A exhibited the highest antifungal activity at all concentrations and showed greater inhibition than the standard drug Ketoconazole at higher concentrations. Compounds B and C displayed moderate antifungal activity with comparatively lower inhibition zones. The graphical representation highlights the strong antifungal potential of compound A against *Penicillium chrysogenum*.

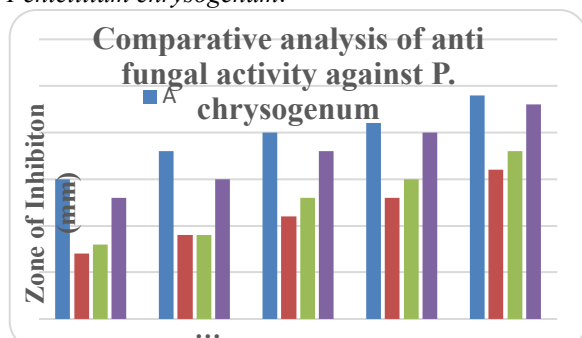


Figure 6: Bar graph showing *Penicillium chrysogenum* antifungal activity

3.2.3 Activity of Antioxidants

DPPH free radical scavenging experiment was used to evaluate the antioxidant ability of the complexes. The results are presented as IC_{50} values and % inhibition. All compounds showed concentration-dependent radical scavenging action, and the percentage inhibition gradually rose from 20 to 100 µg/mL.³²⁻³³

Compound B, which had the lowest IC_{50} value (62.8 ± 1.02 µg/mL) and the highest antioxidant activity ($54.89 \pm 0.12\%$ inhibition at 100 µg/mL), showed a greater capacity to scavenge free radicals. Compound A also shown significant antioxidant potential, with an IC_{50} reading of 81.93 ± 0.61 µg/mL and an inhibition of $53.94 \pm 0.02\%$ at 100 µg/mL. Compound C, on the other hand, had the highest IC_{50} value (97.65 ± 2.80 µg/mL) and comparatively lesser antioxidant activity ($50.09 \pm 0.26\%$).

Compound B has superior antioxidant efficiency in comparison to the other produced compounds, as indicated by its lower IC_{50} value. The compound's functional group's capacity to transfer electrons to neutralize DPPH free radicals may be the cause of the antioxidant effect. Overall, the findings demonstrate that the produced compounds have modest antioxidant activity; among the examined derivatives,

compound B exhibits the strongest antioxidant potential

The antioxidant activities of the generated complexes are represented in form of a bar graph (**Figure 7**) as measured by the DPPH radical scavenging experiment at different dosages. The percentage inhibition increased steadily with concentration, indicating higher dosages of free radical scavenging action. Compound B's lowest IC_{50} value and highest proportion of inhibition showed that the compound had the highest antioxidant capacity of all the chemicals under investigation. Compounds A and C also demonstrated moderate antioxidant activity, however their effects were not as potent as those of compound B. The graphical analysis shows that the generated compounds exhibit discernible antioxidant effects.

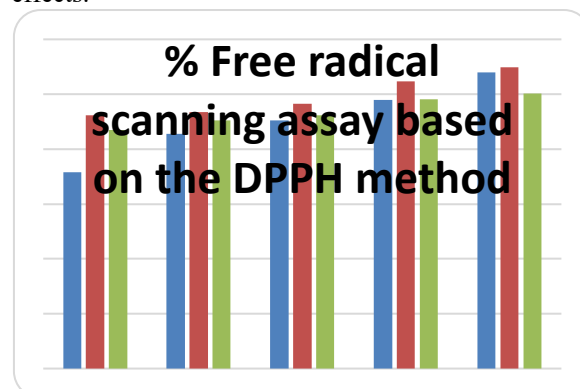


Figure 7: Dose-Dependent Antioxidant Activity of Synthesized Complexes

3.2.4 Anti-inflammatory Assay

Heat-induced bovine serum albumin (BSA) denaturation assay was used to determine the anti-inflammatory efficacy.³⁴⁻³⁵ The anti-inflammatory effect of synthetic complexes at various concentrations ranging from 20 to 100 µg/mL is shown in the bar graph (**Figure 8**). As the concentration rose, the percentage inhibition progressively risen, indicating that greater doses had more potent anti-inflammatory effects.

The lower IC_{50} value obtained for compound B indicates better inhibition of protein denaturation and stronger anti-inflammatory potential relative to other samples. The anti-inflammatory activity may be associated with the ability of the compounds to stabilize proteins against heat-induced denaturation, which is considered one of the mechanisms involved in inflammatory processes. Among the synthesized derivatives, compound B exhibited the highest anti-inflammatory activity, showing $48.11 \pm 0.33\%$ inhibition at 100 µg/mL with the lowest IC_{50} value (109.13 ± 3.57 µg/mL). Compound C showed moderate activity with $44.82 \pm 0.42\%$ inhibition and an IC_{50} value of 169.92 ± 3.47 µg/mL, while

compound A demonstrated comparatively lower activity with $42.81 \pm 0.42\%$ inhibition and an IC_{50} value of $146 \pm 2.82 \mu\text{g/mL}$. The graphical results suggest that the synthesized compounds possess appreciable anti-inflammatory potential, with compound B emerging as the most active derivative.

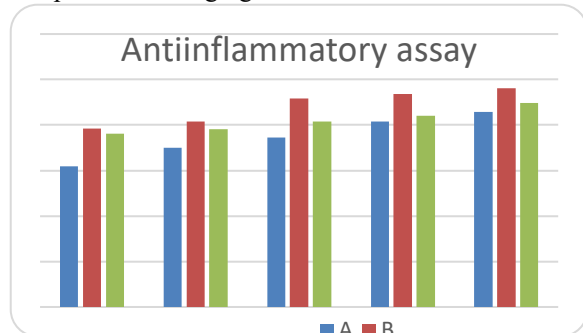


Figure 8: Dose-Dependent Anti-inflammatory Activity of Synthesized Compounds

4. CONCLUSION

The synthesized complexes showed moderate antibacterial with appreciable antifungal activities. Antibacterial results showed a steady but less activity than Azithromycin which is indicative of a low efficacy against bacterial strains. On the other hand, antifungal screening results were promising with *Aspergillus niger* and *Penicillium chrysogenum*. The compound A was the most active derivative with activity indices >1.0 , showing a better potency than Ketoconazole in some cases. The results indicate that structural modifications of the synthesized compounds may be beneficial for antifungal activity as compared to antibacterial effects and may be suitable lead molecules for further optimization, while the β -diketone-containing complex demonstrated enhanced antioxidant and anti-inflammatory properties. The improved biological performance may be attributed to chelation effects and increased electronic delocalization within the mixed-ligand framework. Overall, the study demonstrates that mixed-ligand coordination is a useful method for adjusting the structural, spectral, and biological characteristics of oxovanadium complex compounds. These results underline the synthesized complex's potential as viable subjects for further medical research. Future applications in the biological, pharmacological, and physiological domains might greatly benefit from our current study.

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