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ORIGINAL ARTICLE

Metal complexes used as anti-inflammatory agents: Synthesis, characterization and anti-inflammatory action of VO(II)-complexes

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KEYWORDS

Anti-inflammatory;
2-Imino 4-thiobiuret;
4-Methoxybenzaldehyde and VO(II) complexes

Abstract The anti-inflammatory activity of the vanadium complexes has been studied using the carrageenan induced hind paw oedema method in albino rats (Wister strain). The coordination complexes of VO (II) with the Schiff base derived from 4-aminoacetophenone, 1-acetonaphthone and 4-methoxybenzaldehyde with 2-imino 4-thiobiuret; 3-acetoxypyridine with 2-amino 4-benzathiazol and 4-chloro aniline with salicylaldehyde have been synthesized and characterized by micro analytical data, FT-IR, electronic spectra and FAB-mass spectral studies. The Schiff base ligands behave as bidentated. The stoichiometry of the complexes is in 1:2 and 1:1 (M:L) ratio. The oxovanadium complexes in general show maximum inhibition percentage at about 1 h. After 1 h it goes on reducing and reaches a minimum at about 5 h. Complex-3 (91.17%) and Complex-5 (85.30%) are most potent in in vivo experiment and exhibited promising anti-inflammatory activity in 0.5 h.

1. Introduction

Inflammation, angiogenesis and remodelling are self limiting processes under normal healing conditions. Angiogenesis is a fundamental process for normal and abnormal tissue growth and repair, which consists of recruiting endothelial cells towards an angiogenic stimulus. However, if one or more of those processes are maintained further injury is caused resulting in chronic inflammatory conditions. Chronic inflammatory processes such as rheumatoid arthritis, Crohn's disease and psoriasis share these abnormal healing features. Thus, therapies that attenuate inflammatory angiogenesis and fibrotic processes are able to prevent progression and/or maintenance of chronic inflammatory conditions.

This finding recognized the importance of vanadium biochemistry and stimulated studies on vanadium in many enzyme systems. The Schiff bases have been the subject of great interest for a number of years because of their various chemical and structural characteristics, and also their proved

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applications as biologically active molecules. Their complexes are known to be biologically important and act as models to understand the structure of biomolecules and metalloproteins. They have also a variety of applications, including biological, clinical, analytical and industrial purposes. With increasing incidence of deep mycosis in recent years, there were more and more studies for screening new and more effective antimicrobial broad-spectrum drugs with low toxicity. The interest in the study of Schiff bases and their complexes containing oxygen and Journal of the nitrogen donor atoms arises from their significant antifungal activities. The imine bond in Schiff bases can be easily reduced to give amino derivatives. The comparison of the ligand coordinating properties of reduced Schiff bases with their Schiff base parents showed that the basicity of N atoms is enhanced and also a greater flexibility as consequence of the hydrogenation of the C═N bond, leading to more stable complexes. For these reasons, the reduced Schiff bases have gained particular attention. Vanadium has therapeutic importance and is known as a cofactor for metalloenzymes. In addition to being a cation, vanadium has analogy with phosphorus and as such is a potent inhibitor for phosphorylases. Because speciation can change the metal's existence in cationic or anionic form, speciation has profound effects on biological systems (Crans et al., 2013).

In the present work we studied the effects of the Vanadium Schiff base complexes and Carrageenan induced paw oedema in an experimental model of inflammatory angiogenesis induced by a sponge implant in order to characterize probable synergistic effects between the metal and the standard drug on experimental models. The effects of the vanadium complexes on the selected experimental model of the fibro-vascular tissue were investigated.

Most oxo-vanadium complexes exhibit an onset of action within 0.5–5 h after administration. Maps of pharmacokinetic\pharmacodynamic relation in carrageenan anti-inflammation define activity relationship in these complexes.

2. Material and methods

2.1. Materials

4-Aminoacetophenone, 1-acetonaphthone, 2-imino 4-thiobiuret; 3-acetoxypyridine, 2-amino 4-benzathiazol, 4-chloro aniline, salicylaldehyde, and vanadyl sulphate ($VOSO_4{\cdot}xH_2O$) were purchased from Sigma–Aldrich USA. Ethanol, Methanol, Acetone, Petroleum ether and all used solvents were purchased from Merck, India. The thin layer chromatography plates were obtained from Merck (silica gel 60 F254 grade, Germany). All other chemicals used were of analytical grade. Elemental analysis and FAB-mass spectra were recorded at SAIF-CDRI, Lucknow. FT-IR (in KBr) and Electronic spectra were recorded at Dr. H.S. Gour University, Sagar (M.P.), India.

2.2. Synthesis

2.2.1. Synthesis of Schiff base

Schiff base has been synthesized by adding the methanolic solution of aldehyde or ketone with methanolic solution of amine in 1:1 equimolar ratio. The reaction mixture was then refluxed for 5–8 h. The reaction was completed, and the mixture was allowed to stand overnight, after which the coloured solid was obtained. It was filtered off, recrystallized thrice with ethanol, finally washed with ether, and dried under reduced pressure over anhydrous $CaCl_2$ in desiccators. The purity of the synthesized compounds was monitored by TLC using silica gel-G.

2.2.2. Synthesis of complex

The VO(II) metal complex has been prepared by mixing the methanolic solution of $VOSO_4{\cdot}nH_2O$ with the methanolic solution of Schiff base in 1:1 and 1:2 M ratio. The resulting mixture was refluxed on water bath for 8–9 h. The volume of solvent was reduced until precipitation began, and the mixture was allowed to stand overnight, after which the coloured solid was obtained. It was filtered off, recrystallized thrice with ethanol, finally washed with ether, and dried under reduced pressure over anhydrous $CaCl_2$ in desiccators. The purity of the synthesized compounds was monitored by TLC using silica gel-G.

2.3. Characterization

The oxo-vanadium complexes are coloured, solid and stable towards air and moisture at room temperature. The stability was checked by taking melting point (Table 1) of the complexes at an interval of 24 h and 48 h. However the metal complexes of oxo-vanadium were insoluble in water. Solubility was found in methanol, ethanol and chloroform. Analytical data of the compounds, together with their physical properties are consistent with proposed molecular formula Table 1. The structure of the complexes established from the elemental analysis, FT-IR, UV–vis, FAB-mass, etc., agrees well with the proposed structures of metal complexes as shown in Fig. 1.

A careful comparison of the VO(II)-complexes resulting following information regarding coordination through various groups (Silverstein et al., 1991). The FAB-mass spectra of VO(II)-complexes have been studied. The peaks of appreciable intensity have been observed indicating the fragmentation pattern (Nakamato, 1998; Lever, 1984).

2.3.1. Infrared spectra

The IR spectra (Figs. 3–5) of $[VO(AAIT)(H_2O)_2]$, $[VO(ANIT)(H_2O)_2]$ and $[VO(MBIT)(H_2O)_2]$ give medium intensity band at about 1620 ± 15 due to the νC═N (azomethine) group. This band shifted down by 30–50 cm^{-1} suggesting coordination through azomethine nitrogen. Some peaks are observed at 3176 ± 15 due to νC-H through aromatic, 764 ± 15 due to νN-N. A characteristic non-ligand sharp band at 974–985 cm^{-1}, has been assigned to νV═O. Some bands of low intensity in the region 400–550 cm^{-1} have been attributed to νV-S and νV-N. The IR spectra of $[VO(SCA)_2]{\cdot}3H_2O$ and $[VO(AAMB)_2]{\cdot}3H_2O$ complexes give strong band in 1270 ± 20 cm^{-1} due to deprotonation of phenolin νO-H. The appearance of broad band around 3200–3400 cm^{-1} in the spectra of complexes may be due to associated lattice water molecules. A characteristic non-ligand sharp band at 980–985 cm^{-1}, has been assigned to νV═O. Some bands of low intensity in the region 400–550 cm^{-1} have been attributed to νV-S and νV-N.

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Table 1 Analytical and physical data of the metal complexes.

Complexes	Mol. weight	Yield	Colour/decomposition temp. (°C)	Elemental [found (cal.)] %			
				C	H	N	V
1. VO(AAIT)	489.27	94.43	Golden brown/196	24.55 (25.1)	2.67 (2.64)	14.31 (14.50)	10.41 (10.8)
2.VO(ANIT)	524.31	98.76	Magnolia/190	32.04 (31.99)	2.69 (2.57)	10.69 (10.70)	9.27 (9.28)
3.$VO(SCA)_2$	717.32	95.89	Yellow/258	32.15 (32.10)	2.07 (2.05)	2.88 (2.90)	10.49 (10.45)
4.VO(MBIT)	490.25	98.87	Cream/200	24.49 (24.45)	2.47 (2.50)	11.43 (11.40)	10.39 (10.40)
5.$VO(AAMB)_2$	820.68	97.65	Orange/260	33.53 (33.57)	2.44 (2.43)	7.82 (7.85)	9.48 (9.51)

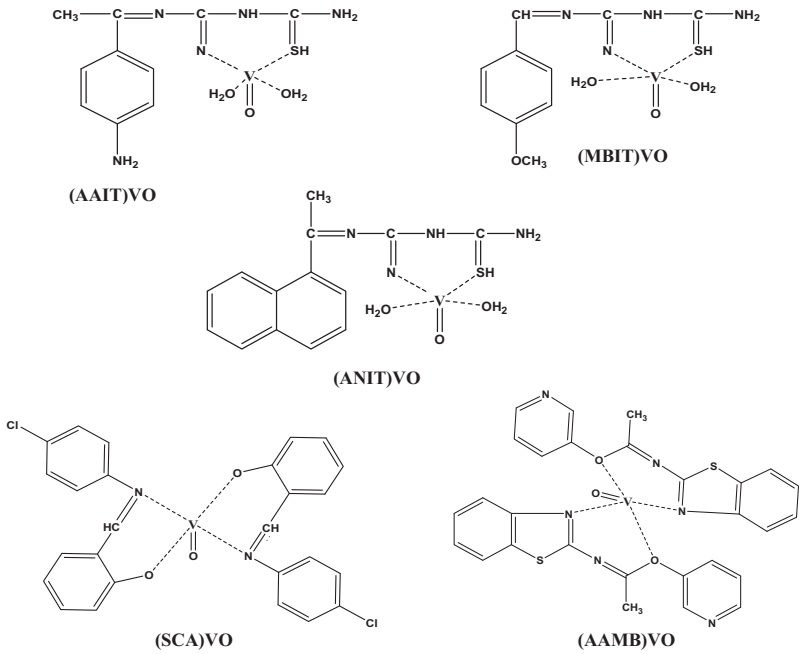

Figure 1 Proposed structure of VO(II)-complexes.

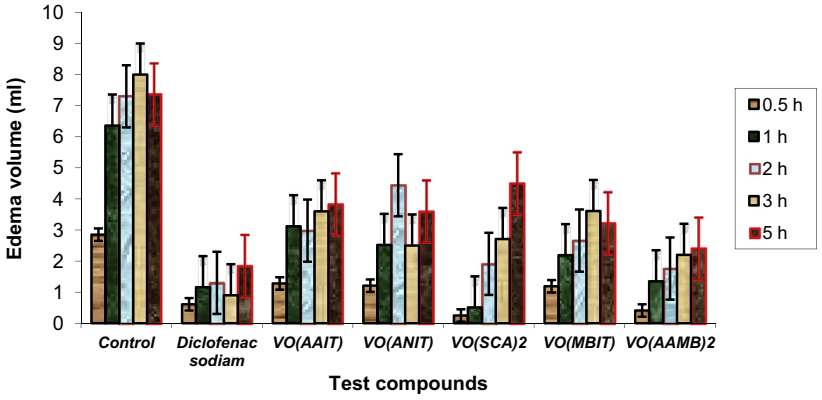

Figure 2 Effect of VO(II)-complexes on carrageenan induced rat paw oedema.

2.3.2. Electronic spectra and magnetic moment

Room temperature magnetic moments of the VO-complexes lay in the range 1.70–1.80 BM. The values are well suited for the VO(II)-monomeric and dimeric complexes with one unpaired electron. The electronic spectra (in methanol) of VO(AAIT), VO(ANIT) and VO(MBIT)-complexes exhibit bands in regions: 13790–14285, 16806–20000 and 23150–24000 cm^{-1}; the transition has been assigned due to $^2B_2 \rightarrow {}^2E$, $^2B_2 \rightarrow {}^2B_1$ and $^2B_2 \rightarrow {}^2A_1$, respectively. At least minimum of two or three bands have been observed clearly in these complexes. The geometry of these neutral five coordinated mononuclear and binuclear complexes can be described in terms of a trigonal bipyramidal, distorted towards a tetragonal pyramidal or square pyramidal. The $VO(SCA)_2$ and $VO(AAMB)_2$ complexes exhibit bands in

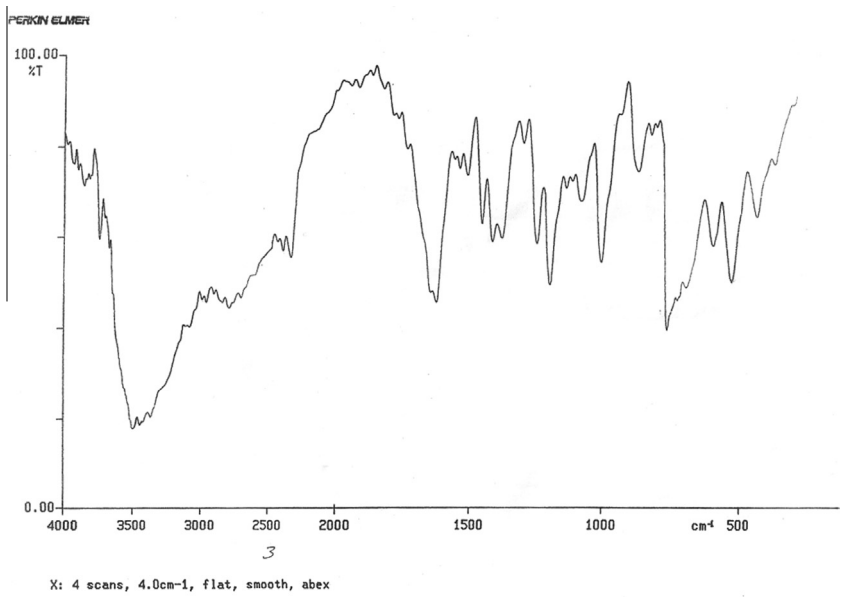

Figure 3 FT-IR spectrum of VO(AAIT)-complex.

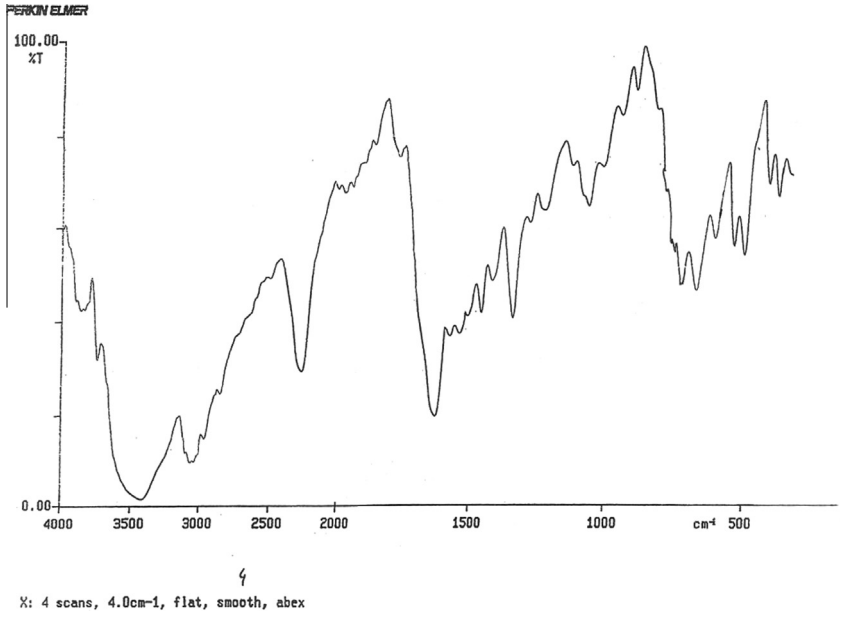

Figure 4 FT-IR spectrum of VO(ANIT)-complex.

regions: 12900–14000, 15800–18100 and 21000–23020 cm^{-1}; which are assigned due to $^2B_2 \rightarrow {}^2E$, $^2B_2 \rightarrow {}^2B_1$ and $^2B_2 \rightarrow {}^2A_1$ transitions, respectively. Octahedral geometry has been suggested for six coordinated complexes. In the octahedral complexes due to the presence of sixth donor ligand (H_2O), trans to terminal V═O bond, has a direct influence on ligand field, the d–d transitions here are slightly shifted higher compared to the corresponding positions in trigonal bipyramidal or square pyramidal complexes.

2.3.3. FAB-mass

The FAB-mass spectra (Fig. 6) of [VO(AAIT)$(H_2O)_2$], [VO(ANIT)$(H_2O)_2$] and [VO(MBIT)$(H_2O)_2$] complexes have been studied. The peaks of appreciable intensity have been observed for [VO(AAIT)$(H_2O)_2$] at m/z values obs. (cal.): 492 (489), 474 (471), 450 (453), 210 (218) and 169 (167) which indicate the fragmentation pattern. The m/z value 492 corresponds to the nearest composition [VO(AAIT)$(H_2O)_2$], 474 to [VO(AAIT)H_2O], 450 to [VO(AAIT)], 210 to ligand alone and 169 to VO with the chelated O and N ligand moiety. The peaks of appreciable intensity have been observed for [VO(ANIT)$(H_2O)_2$] at m/z values obs. (cal.): 528 (524), 510 (506), 480 (488), 216 (218) and 170 (168) which indicate the fragmentation pattern. The m/z value 528 corresponds to the nearest composition [VO(ANIT)$(H_2O)_2$], 510 to [VO(AAIT)H_2O], 480 to [VO(AAIT)], 216 to ligand alone and 170 to VO with the chelated O and N ligand moiety. [VO(MBIT)$(H_2O)_2$] at m/z values obs. (cal.): 499 (490), 470

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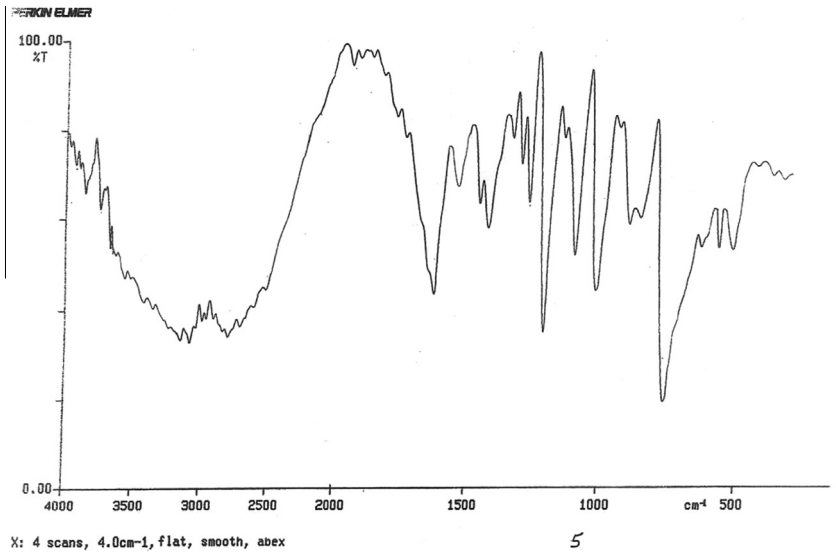

Figure 5 FT-IR spectrum of $VO(SCA)_2$-complex.

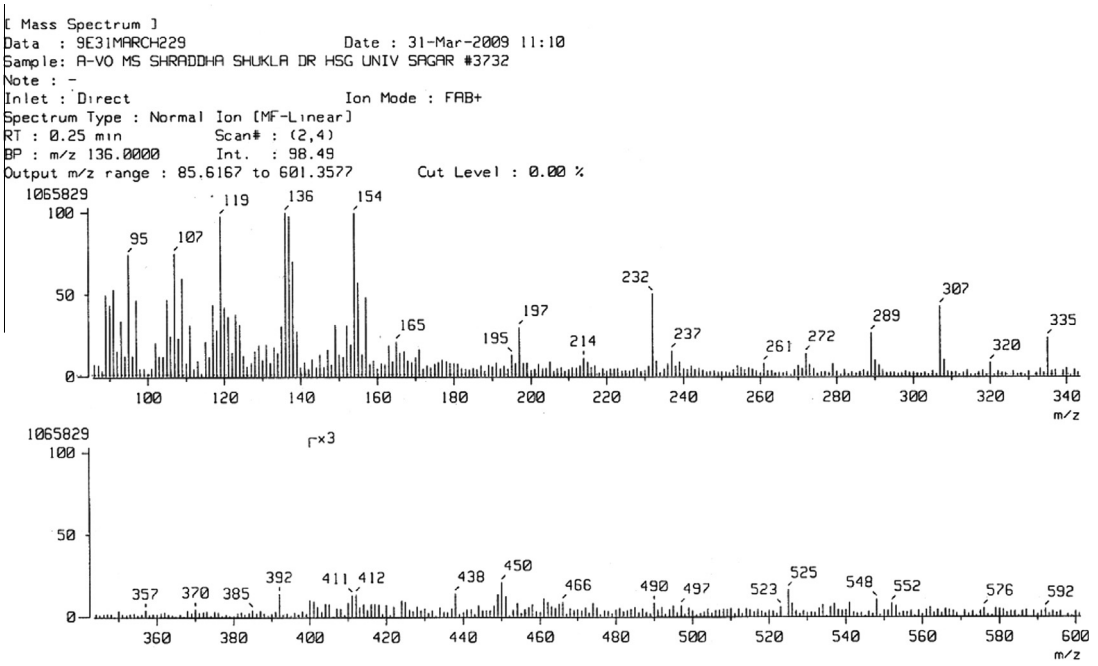

Figure 6 FAB-mass spectrum of VO(ANIT)-complex.

(472), 459 (454), 216 (219) and 171 (169) indicate the fragmentation pattern. The *m*/*z* value 499 corresponds to the nearest composition $[VO(MBIT)(H_2O)_2]$, 470 to $[VO(AAIT)H_2O]$, 459 to [VO(AAIT)], 216 to ligand alone and 171 to VO with the chelated O and N ligand moiety. These complexes have a similar fragmentation pattern that shows 1:1 stoichiometry.

$[VO(SCA)_2]\cdot 3H_2O$ and $[VO(AAMB)_2]\cdot 3H_2O$ have been studied. $[VO(SCA)_3]\cdot 3H_2O$ at *m*/*z* values obs. (cal.): 721 (717), 695 (699), 669 (663), 430 (432), 199 (201) and 155 (151) indicate the fragmentation pattern. The *m*/*z* value 721 corresponds to the nearest composition $[VO(SCA)_2]\cdot 3H_2O$, 695 to $[VO(SCA)_2]2H_2O$, 669 to $[VO(SCA)_2]$, 430 to [VO(SCA)], 199 to ligand alone and 155 to VO with the chelated O and N ligand moiety. $[VO(AAMB)_2]\cdot 3H_2O$ at *m*/*z* values obs. (cal.): 827 (820), 800 (802), 769 (760), 480 (483), 199 (200) and 149 (151) indicate the fragmentation pattern. The *m*/*z* value 827 corresponds to the nearest composition $[VO(AAMB)_2]\cdot 3H_2O$, 800 to $[VO(AAMB)_3]\cdot 2H_2O$, 769 to $[VO(AAMB)_2]$, 480 to [VO(AAMB)], 199 to ligand alone and 149 to VO with the chelated O and N ligand moiety.

2.4. Anti-inflammation assay

2.4.1. Animals

Albino Wister rats of either sex and of approximately the same age, weighing about 150–175 g were used for the study. They were housed in polypropylene cages and fed with standard

chow diet and water ad libitum. The animals were exposed to alternate cycle of 12 h of darkness and light each. Before each test, the animals were fasted for at least 12 h. The experimental protocols were subjected to the scrutinization of the Institutional Animal Ethics Committee and were cleared by the same.

2.4.2. Acute toxicity studies

The animals were divided into control and test groups containing six animals each. The control group received the vehicle (1% acacia gum) while the test groups got graded doses of different concentrations ip and were observed for mortality till 48 h and the LD_{50} was calculated.

2.4.3. Carrageenan induced paw oedema

Anti-inflammatory activity was determined by the paw oedema method in rats described by Winter et al. (1962). The rats were divided into seven groups ($n = 6$). Group I served as the control (saline). Group II was given diclofenac sodium orally (5 mg/kg) as a standard drug. Groups III-VII were administered VO(II)-complexes (5 mg/kg) orally. The mother concentration of VO(II) complexes is 0.5 mmol/ml/kg body weight at 6.5–7 pH. The paw volume was measured by the plethysmographic method at 0.5, 1, 2, 3 and 5 h, after the sub plantar injection of 0.1 ml of 1% freshly prepared suspension of carrageenan (Sigma Chemical Co.) at. Drug pretreatment was given 1 h before the injection of carrageenan. The values have been incorporated in Table 2. The paw volume was measured with the help of a mercury replacement plethysmometer (Model 7140, UGO Basile, Italy) first at zero hour and then at 1–4 h after the administration of drugs. The percentage inhibition of oedema compared with that of the control was taken as anti-inflammatory activity.

Percentage of inhibition (%) = [1-volume in ml (test compound)/volume in ml (control)] × 100.

2.4.4. Statistical analysis

All values were expressed as mean ± standard deviation. All the data were analysed by the one way analysis of variance followed by multiple comparison tests (Tukey's test) at the 5% level of significance. $P < 0.05$ was considered statistically significant.

3. Result and discussion

The Schiff base ligands are amorphous solids and are soluble in most organic solvents at room temperature and at slightly higher temperatures. The oxo-vanadium complexes of these ligands were synthesized by treating the methanolic solution of $VOSO_4{\cdot}nH_2O$ with the methanolic solution of Schiff base ligands in1:1 [complex-1,2 & 4] and 1:2 [complex-3 & 5] molar ratio from the condensation. The purity of the complexes was checked by TLC. All oxo-vanadium complexes are stable in air, non-hygroscopic and melt above 190–260 °C. Elemental analysis reveals 1:1 and 1:2 metal to ligand stoichiometry. Spectroscopic data (FT-IR, FAB-mass, Electronic, etc.) confirmed the structure of the complexes (Fig. 1). The FT-IR spectrum of the complexes indicates the coordination through carbonyl oxygen, azomethine nitrogen and thiolic sulphur. The absence of ν(OH) in the IR spectra is indicative of the coordination of phenolic oxygen by the loss of a proton. The geometry of electronic spectra and magnetic moment of neutral five coordinated mononuclear and binuclear VO(AAIT), VO(ANIT) and VO(MBIT) complexes was assigned trigonal bipyramidal, distorted towards a tetragonal pyramidal or square pyramidal; six coordinated $VO(SCA)_2$ and $VO(AAMB)_2$ complexes were assigned octahedral geometry. The FAB-mass spectra of complexes confirmed molecular weight and fragmentation pattern of the oxo-vanadium complexes.

Perusal of Table 2 and Fig. 2 shows that all the five VO(II)-complexes efficiently act to inhibit the inflammation. The results are comparable to the standard drug Diclofenac sodium. The distinct feature of diclofenac sodium is that the effect from 0.5 to 5 h has a regular trend and the value decreases to 74.93% at 5 h, ranging from 75% to 89%. Thus the average efficiency of the standard drug is more than 75%. The test complexes in general show maximum inhibition percentage at about 1 h. After 1 h it goes on reducing and reaches a minimum at about 5 h. Basically inflammation is a protective response to cell injuries in animals. It is manifested in the form of common clinical signs such as erythema, oedema, hyperalgesia and pain and loss of function at macroscopic level. To study the anti-inflammatory activity of any complexes the suppression of these signs is observed in laboratory animals. This includes using three models *viz*. acute, subacute and chronic. In the present study carrageenan induced acute inflammation model has been used for studies. The results have been compared with the standard drug diclofenac sodium which is categorized as a NSAID (Non-steroid anti-inflammatory drug) this category of drugs acts at the periphery and not at the CNS. Acting at the site of tissue injury these drugs block the synthesis of eicosanoids, finally blocking the cyclooxygenase (COX) pathway. Vanadium complexes are showing moderate to very good anti-inflammatory activity up to 1 h, which goes on reducing with the time. The probable mechanism of action of carrageenan induced oedema is bi-phasic; the first phase is attributed to the release of histamine – HT

Table 2 Effect of VO(II)-complexes on carrageenan induced rat paw oedema.

Groups ($n = 6$)	Oedema volume (ml) [mean of inhibition (%)]				
	0.5 h	1 h	2 h	3 h	5 h
1. Control (saline)	2.85 ± 0.24	6.36 ± 0.96	7.30 ± 0.72	8.00 ± 0.84	7.36 ± 0.89
2. Diclofenac sodium	0.61 ± 0.20 [78.44]	1.16 ± 0.37 [81.73]	1.30 ± 0.40 [82.34]	0.90 ± 0.40 [88.94]	1.85 ± 0.46 [74.93]
3. VO(AAIT)	1.28 ± 0.29 [54.77]	3.12 ± 0.38 [50.87]	2.98 ± 0.50 [59.51]	3.60 ± 0.43 [55.99]	3.83 ± 0.60 [38.34]
4. VO(ANIT)	1.21 ± 0.42 [57.03]	2.52 ± 0.49 [60.22]	4.44 ± 0.59 [39.67]	2.50 ± 0.42 [69.43]	3.60 ± 0.45 [51.21]
5. $VO(SCA)_2$	0.25 ± 0.14 [91.17]	0.51 ± 0.34 [91.95]	1.91 ± 0.34 [74.04]	2.71 ± 0.45 [66.87]	4.50 ± 0.48 [39.03]
6. VO(MBIT)	1.19 ± 0.15 [57.84]	2.19 ± 0.44 [65.86]	2.66 ± 0.52 [63.86]	3.16 ± 0.57 [61.30]	3.22 ± 0.16 [56.37]
7. $VO(AAMB)_2$	0.41 ± 0.23 [85.30]	1.35 ± 0.44 [78.74]	1.76 ± 0.34 [76.01]	2.20 ± 0.46 [73.10]	2.41 ± 0.48 [67.26]

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and kinins in the first hour while the second phase is attributed to the release of prostaglandin like substance in 2–3 h. The activity of VO(II)-complexes is structure dependent and is excellent in inhibiting carrageenan induced oedema. The substitution in the benzene ring at 1 position by the sulphonomide group enhances anti-inflammatory activity significantly. It can be observed that complex-3 $[VO(SCA)_2]$ has better activity compared to the standard drug at 0.5 h (91.17%). Further complex complex-5 $[VO(AAMB)_2]$ also has activity greater than the standard drug at 0.5 h (85.30%). Although structure activity relationship with such a small number of observations cannot be established one thing is clear that the oxo-vanadium(II) complexes can be potential anti-inflammatory drugs if explored further.

4. Conclusion

The VO(II) metal complexes have been designed and synthesized. Spectral and analytical data evidence the bidentated nature of the ligand coordinating through, azomethine nitrogen, thiolic sulphur and phenolic oxygen with the loss of a proton. The geometry of neutral five coordinated mononuclear and binuclear VO(AAIT), VO(ANIT) and VO(MBIT) complexes was assigned trigonal bipyramidal, distorted towards a tetragonal pyramidal or square pyramidal; six coordinated $VO(SCA)_2$ and $VO(AAMB)_2$ complexes were assigned octahedral geometry. The tentatively proposed structure for the oxo-vanadium complexes is given in Fig. 1. The anti-inflammatory activity of the complexes is moderate, among the complexes reported here, complex-3 $[VO(SCA)_2]$ and 5 $[VO(AAMB)_2]$ have shown high percentage inhibition compared with the standard drug Diclofenac sodium. The anti-inflammatory activities of all oxo-vanadium complexes show promising results. Among the complexes, complex-3 $[VO(SCA)_2]$ has shown the highest activity and is even more than the standard itself. In future these complexes will be used as anti-inflammatory agents.

Acknowledgments

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References

Crans, D.C., Woll, K.A., Prusinskas, K., Johnson, M.D., Norkus, E., 2013. Inorg. Chem. 52 (21), 12262–12275.
Lever, A.B.P., 1984. Inorganic Electronic Spectroscopy, Second ed. Elsevier, Amsterdam.
Nakamato, K., 1998. Infrared and Raman Spectra of Inorganic and Coordination Compounds; Part A and B. John Wiley and Sons Inc., New York.
Silverstein, R.M., Bassler, G.C., Morill, T.C., 1991. Spectrometric Identification of Organic Compounds, fifth ed. John Wiley and Sons Inc., New York.

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