



# Synthesis, Crystal Structure and Spectroscopic Study of (*E*)-2-methoxy-4-((1-phenylethylimino)methyl)phenol

**Bocar Traoré <sup>a\*</sup>, Grégory Excoffier <sup>b</sup>, Alioune Fall <sup>a</sup>,  
Ibrahima Elhadj Thiam <sup>a</sup>, Mamadou Sidibé <sup>a</sup>,  
Ousmane Diouf <sup>a</sup> and Mohamed Gaye <sup>a</sup>**

<sup>a</sup> Department of Chemistry, University Cheikh Anta Diop, Dakar, 10700, Sénégal.

<sup>b</sup> Aix-Marseille Université, CNRS, Centrale Marseille, FSCM, Spectropole, Marseille, France.

## **Authors' contributions**

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

## **Article Information**

DOI: 10.9734/CSJI/2023/v32i6877

## **Open Peer Review History:**

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here:

<https://www.sdiarticle5.com/review-history/110477>

**Original Research Article**

**Received: 16/10/2023**

**Accepted: 22/12/2023**

**Published: 28/12/2023**

## **ABSTRACT**

A new unsymmetrical ligand (*E*)-2-methoxy-4-((1-phenylethylimino)methyl)phenol C<sub>16</sub>N<sub>17</sub>NO<sub>2</sub> (**I**), was synthesized by one-step condensation reaction. The structure of this new compound was confirmed by elemental analysis, FT-IR, UV-Visible and <sup>1</sup>H and <sup>13</sup>C NMR spectroscopy techniques. The compound (**I**) crystallizes in the orthorhombic space group P2<sub>1</sub>2<sub>1</sub>2<sub>1</sub> with the following unit cell parameters a = 11.7570 (6) Å, b = 10.0711 (6) Å, c = 23.4478(13) Å, V = 2776.4(3) Å<sup>3</sup>, Z = 4, R<sub>1</sub> = 0.045 and wR<sub>2</sub> = 0.125. The title compound crystallizes with two enantiomers (A and B) in the asymmetric unit which are both in *E*-stereoisomers. In the crystal structure of the racemic compound, the most noticeable difference between these two molecules is the dihedral angle values between the phenyl rings: 61.61 (1)° and 60.96(1)°.

\*Corresponding author: E-mail: bocar.traore@ucad.edu.sn;

**Keywords:** 4-hydroxy-3-methoxybenzaldehyde; 1-phenylethanamine; NMR; UV-Visible; X-ray.

## 1. INTRODUCTION

“Over the past two decades, vanillin has been widely used as a source of Schiff bases due to its ability to react rapidly with primary aliphatic amino and amino aromatic compounds. These compounds which can present donor sites such as O or N are ligands widely used in coordination chemistry to develop complex materials with original properties” [1-3]. Depending on their topology and the nature of the substituents, they can interact with various metal ions such as bidentate [4,5], tridentate [5,6] or tetradentate [7, 8] ligands. “These ligands can also act in their neutral or deprotonated forms because of the keto-enolic equilibrium which can be established in solution” [9-11]. Several works in coordination chemistry involving ligands derived from vanillin have generated compounds with interesting properties [12,13]. Antioxidant properties acting positively on the prevention and treatment of cancer [14,15], inflammatory diseases [16], cardiovascular diseases [17], and neurodegenerative diseases [18] have been reported in the literature. In continuing our work in this area, we isolated the ligand (*E*)-2-methoxy-4-((1-phenylethylimino)methyl)phenol from the condensation reaction between *p*-vanillin and 1-phenylethanamine. The structure of the ligand was elucidated by elemental analyses, FT-IR and NMR spectroscopic studies and X-ray diffraction [19,20]. The ligand crystallizes with two enantiomers (*A* and *B*) in the asymmetric unit.

## 2. METHODOLOGY

### 2.1 Starting Materials and Instrumentations

4-hydroxy-3-methoxybenzaldehyde and 1-phenylethanamine were purchased from Aldrich and used without any further purification. The solvents and reagents were of good quality and were purified by usual methods. Elementary analyses were carried out in a Carlo-Erba EA microanalyzer. Infrared spectra were recorded with a Perkin Elmer Spectrum Two FT-IR spectrometer in the 4000-400  $\text{cm}^{-1}$  region. The  $^1\text{H}$  NMR spectrum was recorded in  $\text{DMSO-d}_6$  on a Bruker 500 MHz spectrometer at room temperature using TMS as an internal reference.

UV-Vis spectra were run on a Perkin-Elmer Lambda 365 UV/Visible spectrometer (1000-200 nm).

### 2.2 Synthesis of the Ligand

*p*-Vanillin (2 g, 13.145 mmol) was dissolved in a vial containing 20 mL of methanol. 1-phenylethanamine (1.6 g, 13.145 mmol) and two drops of glacial acetic acid were added successively. The reaction mixture is brought to reflux for 4 hours. The resulting pink solution was filtered hot. After cooling, the resulting clear solution was left to slowly evaporate. Pink crystals were isolated after few days. Yield: 80%. Tf:  $> 260^\circ\text{C}$ . Anal. Calc. for  $[\text{C}_{16}\text{H}_{17}\text{NO}_2]$  (%): C, 75.27; H, 6.71; N, 5.49. Found: C, 75.22; H, 6.70; N, 5.90. IR ( $\nu$ ,  $\text{cm}^{-1}$ ): 3200, 3080, 2980, 1628, 1577, 1513, 1396, 1262, 1026, 865, 826, 769, 699.  $^1\text{H}$  NMR [ $\text{DMSO-d}_6$ ;  $\delta$ (ppm)]: 1.56 (d, 3H,  $-\text{CH}_3$ ), 3.73 (s, 3H,  $-\text{OCH}_3$ ), 4.59 (q, 1H,  $-\text{CH}-\text{N}$ ), 8.11 (s, 1H,  $\text{H}-\text{C}=\text{N}$ ), 6.65-7.25 (8H,  $\text{H}_{\text{Ar}}$ ), 12 (s, 1H,  $\text{H}$ -phenol).

### 2.3 Crystal Structure Determination

“Crystals suitable for X-diffraction, of the reported compound, were grown by slow evaporation of MeOH solution of the complex. Details of the X-rays crystal structure solution and refinement are given in Table 1. Diffraction data were collected using an automatic XtaLAB AFC12 (RINC): Kappa single type diffractometer with graphite monochromatized  $\text{MoK}\alpha$  radiation ( $\lambda = 0.70173 \text{ \AA}$ ). All data were corrected for Lorentz and polarization effects. No absorption correction was applied. Complex scattering factors were taken from the program package SHELXTL” [21]. “The structures were solved by direct methods which revealed the position of all non-hydrogen atoms. All the structures were refined on  $F^2$  by a full-matrix least-squares procedure using anisotropic displacement parameters for all non-hydrogen atoms” [22]. “The hydrogen atoms of OH groups were located in the Fourier difference maps and refined. Others H atoms (CH and  $\text{CH}_3$  groups) were geometrically optimized and refined as riding model by AFIX instructions. Molecular graphics were generated using ORTEP-3” [23].

**Table 1. Crystallographic data and refinement parameter for the compound (I)**

Chemical formula	C <sub>32</sub> H <sub>34</sub> N <sub>2</sub> O <sub>4</sub>
<i>M</i> <sub>r</sub>	510.61
Crystal system, space group	Orthorhombic, <i>P</i> 2 <sub>1</sub> 2 <sub>1</sub> 2 <sub>1</sub>
Crystal size (mm)	0.20 × 0.15 × 0.02
<i>a</i> (Å)	11.7570 (6)
<i>b</i> (Å)	10.0711 (6)
<i>c</i> (Å)	23.4478 (13)
<i>V</i> (Å <sup>3</sup> )	2776.4 (3)
<i>Z</i>	4
<i>D</i> <sub>calc</sub> (g.cm <sup>-3</sup> )	1.222
<i>I</i> (Cu Kα) (Å)	1.54187
<i>T</i> (K)	296
<i>μ</i> (mm <sup>-1</sup> )	0.64
<i>F</i> (000)	1088
□ range (°)	3.770-77.246
No. of measured reflections	19470
No. of independent reflections	5862
No. of observed [ <i>I</i> > 2σ( <i>I</i> )] reflections	5001
<i>R</i> <sub>int</sub>	0.030
<i>R</i> [ <i>F</i> <sup>2</sup> > 2σ( <i>F</i> <sup>2</sup> )]	0.045
<i>wR</i> ( <i>F</i> <sup>2</sup> )	0.125
Goodness-of-fit ( <i>Gof</i> ) on <i>F</i> <sup>2</sup>	1.03
No. of reflections	5862
No. of parameters	359
No. of restraints	0
Δρ <sub>max</sub> , Δρ <sub>min</sub> (e Å <sup>-3</sup> )	0.22, -0.19

### 3. RESULTS AND DISCUSSION

#### 3.1 General Study

“The ligand HL was prepared by a facile condensation of *p*-vanillin and 1-phenylethanamine in methanol in 1/1 ratio (Scheme 1). The resulting compound is quantitatively yielded (80 %). The elemental analyses results is in accordance with the chemical formulae obtained from X-ray diffraction study. The infrared spectrum of the compound (I) reveals bands which are in agreement with those of analogous compounds reported in the literature” [24,25]. In fact, the mainly interested band pointed at ca. 1628 cm<sup>-1</sup> is characteristic of the ν<sub>C=N</sub> absorption, thus confirming the formation of the Schiff base. The ν<sub>O-H</sub> (3200 cm<sup>-1</sup>) absorption of the phenolic group, which is expected in the range 3500 cm<sup>-1</sup> and 3300 cm<sup>-1</sup>, is shifted to low frequencies due to the intramolecular hydrogen bond established with the methoxy group situated on the ortho position of the hydroxy group [26]. Bands pointed at ca. 3080 cm<sup>-1</sup> were attributed to C<sub>sp2</sub>-H stretching of the phenyl groups while bands pointed in the range 2800–2900 cm<sup>-1</sup> are due to C<sub>sp3</sub>-H stretching of the aliphatic group.

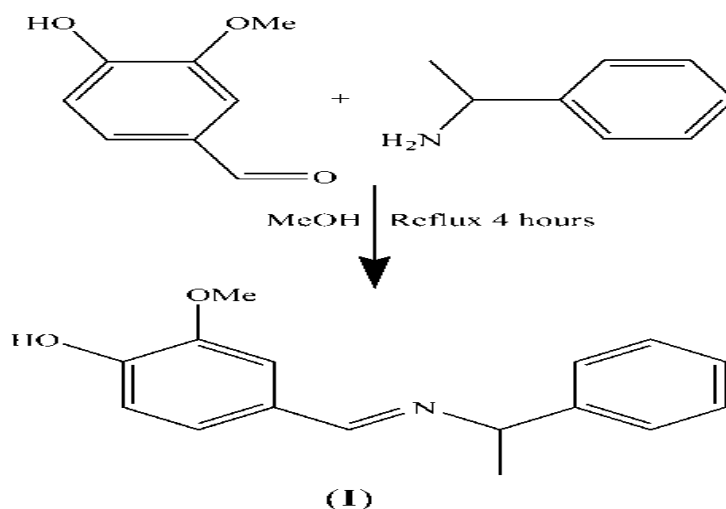
The band characteristic of the presence of aromatic ring are pointed in the range 1577–1450 cm<sup>-1</sup> [27]. In addition, the characteristic bands of deformation vibrations of out-of-plane aromatic C-H bonds are pointed at 865 cm<sup>-1</sup> and 769 cm<sup>-1</sup>. The band which appears at 1262 cm<sup>-1</sup> was assigned to the stretching vibration ν<sub>C-O</sub> of the phenolic group. The <sup>1</sup>H spectrum of the HL ligand was recorded in DMSO (dms<sub>o</sub>-d<sub>6</sub>). The signals at 12 ppm representing one proton is due to the -OH of the phenolic moiety. The -HC=N proton of the azomethine moiety is pointed at 8.11 ppm. Signals at 1.56 ppm, 3.73 ppm and 4.59 ppm are, respectively, assigned to the protons of the methyl groups (CH<sub>3</sub>-C and CH<sub>3</sub>-O) and the proton of the methylidyne group (-CH-N). The electronic spectrum of the organic molecule recorded in DMF solution shows an intense absorption at 307 nm attributed to the π→π\* transitions of the aromatic rings and/or n→π\* of the imine function of the ligand.

#### 3.2 Structure Description of the Compound (I)

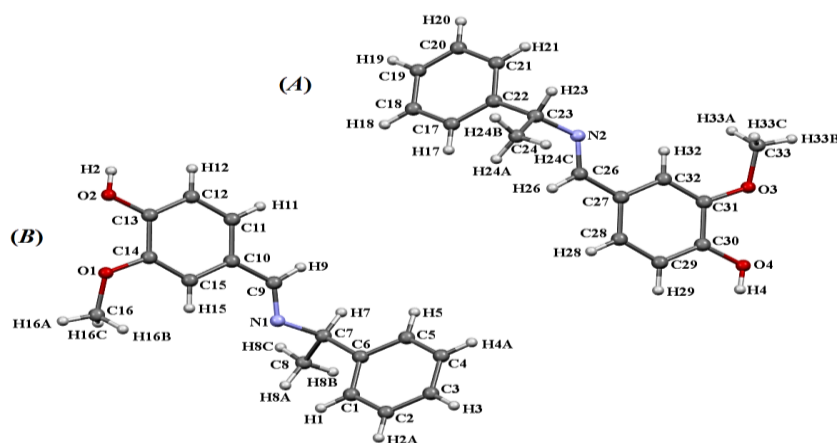
The title compound crystallizes in the orthorhombic system with space group *P*2<sub>1</sub>2<sub>1</sub>2<sub>1</sub>. The asymmetric unit of the title compound (I),

$C_{16}H_{17}NO_2$ , contains two neutral molecules which are enantiomers (Fig. 1). The selected bond lengths and angles are collected in Table 2. The predominant structural feature is the formation of the C=N bonds between the carbonyl carbon atom of the p-vanillin molecules C9/C26 with the amino nitrogen atom of the 1-phenylethanamine molecules N1/N2 [C9–N1 = 1.269(4) Å and C26–N2 = 1.268(4) Å]. These two distances are found to be quite equal and are comparable to those found for similar Schiff bases [28,29]. All other bond lengths and angles are of expected values with C7–N1 [1.480(4) Å], C13–O2 [1.350(3) Å], C14–O1 [1.368(3) Å], C23–N2 [1.484(4) Å], C30–O4 [1.348(3) Å], C31–O3 [1.361(3) Å]. In the isomer A, the methyl group on the asymmetric carbon atom is disordered with two sites having occupancies of 0.7(1) and 0.3(1) for C24 and C25 respectively. The title compound crystallizes

with two enantiomers (A and B) in the asymmetric unit which are both *E*-stereoisomers. In the crystal structure of the racemic compound, the most noticeable difference in the structures of two enantiomers is the dihedral angle values between the phenyl rings : 61.61(1)° for A and 60.96(1)° for B. The 1-Hydroxy-2-methoxy units of the enantiomers A and B are planar (rms = 0.0139 (A), rms = 0.0070 (B)) and are quite parallel with a dihedral angle value of 1.091(2)°. The two phenyl rings of the two units are slightly twisted each other with a dihedral angle value of 4.851(3)°. The crystal packing of compound (I) (Fig. 2) is stabilized by intermolecular hydrogen bonds N(imino)–H...O(phenol). Intermolecular hydrogen bonds, N2(imino)–H2...O2<sup>i</sup>(phenol) (i: 1/2-x, 1-y, -1/2+z), N1(imino)–H4...O4<sup>i</sup>(phenol), (ii: 3/2-x, 1-y, 1/2+z), to the formation of layers parallel to *b* axis (Fig. 2, Table 3).



**Scheme 1. Synthetic scheme for the compound (I)**



**Fig. 1. Molecular structures of both enantiomers (A) and (B) of the title compound with displacement ellipsoids drawn at the 30% probability**

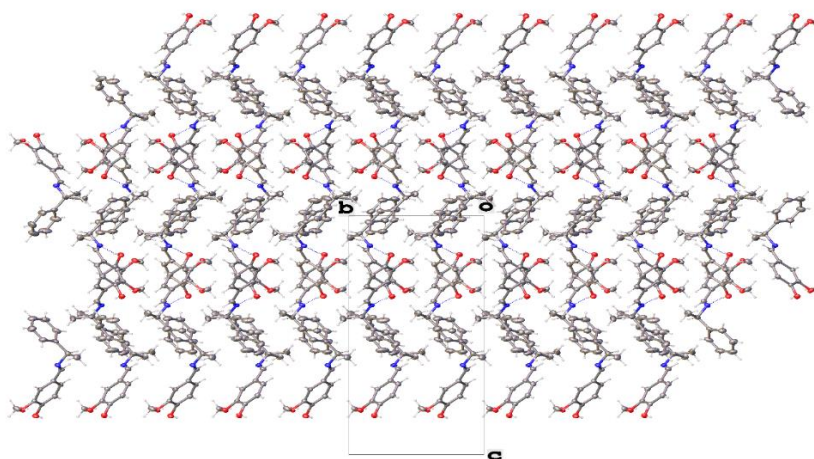


Fig. 2. View along the a axis of the crystal packing of molecule of compound and hydrogen bond

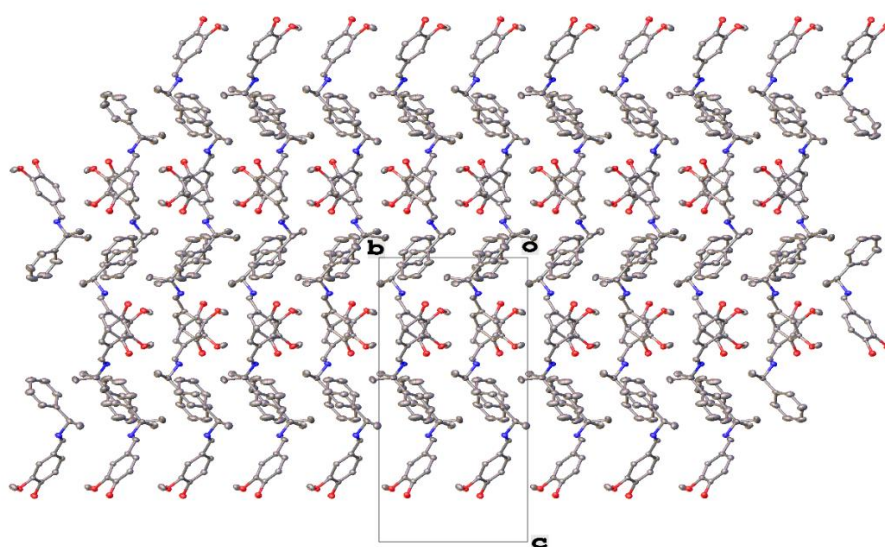


Fig. 3. View along the a axis of the crystal packing of molecule of compound without hydrogen atom

Table 2. Selected bond distances [Å] and angles [deg] for the compound (I)

O2—C13	1.350 (3)	O1—C16	1.413 (4)
O4—C30	1.348 (3)	N2—C26	1.268 (4)
O3—C31	1.361 (3)	N2—C23	1.484 (4)
O3—C33	1.419 (4)	N1—C9	1.269 (4)
O1—C14	1.368 (3)	N1—C7	1.480 (4)
N1—C7—C6	109.7 (3)	C24—C23—N2	117.9 (4)
N1—C7—C8	108.4 (3)	C25—C23—C22	125.8 (6)
C6—C7—C8	113.9 (3)	C24—C23—C22	115.6 (4)
N1—C7—H7	108.2	N2—C23—C22	109.5 (3)
C6—C7—H7	108.2	C24—C23—H23	104.0
C8—C7—H7	108.2	N2—C23—H23	104.0
C25—C23—N2	116.7 (6)	C22—C23—H23	104.0

**Table 3. Hydrogen-bond geometry (Å, °).**

<i>D</i> — <i>H</i> ... <i>A</i>	<i>D</i> — <i>H</i>	<i>H</i> ... <i>A</i>	<i>D</i> ... <i>A</i>	<i>D</i> — <i>H</i> ... <i>A</i>
O2—H2...N2 <sup>i</sup>	0.82	1.88	2.689(3)	168.3
O4—H4...N1 <sup>ii</sup>	0.82	1.93	2.738(3)	166.2

Symmetry code : (i) 1/2-x, 1-y, -1/2+z; (ii) 3/2-x, 1-y, 1/2+z

#### 4. CONCLUSION

In this present work we reported the synthesis of an unsymmetrical (*E*)-2-methoxy-4-((1-phenylethylimino)methyl)phenol C<sub>16</sub>N<sub>17</sub>NO<sub>2</sub> (**I**). The structure of the new Schiff base was discussed by elemental analysis and spectroscopic techniques (FT-IR, UV-visible, <sup>1</sup>H NMR). X-rays diffraction technique was used to determine the molecular structure of (**I**).

#### SUPPLEMENTARY MATERIALS

CCDC-2310613 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge via <https://www.ccdc.cam.ac.uk/structures/> or by contacting The Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge CB2 1EZ, UK.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

#### REFERENCES

- Priyadharshini RS Saravanan M. Synthesis crystal growth crystal structure optical, thermal and NLO studies of Vanillin-3,5-Dinitrosalicylic acid (VDNS)-A novel organic material. *Optics & Laser Technology*. 2023;164:109512. Available:<https://doi.org/10.1016/j.optlastec.2023.109512>
- Shahid M, Salim M, Khalid M, Tahir MN, Khan MU, Braga AAC. Synthetic XRD non-covalent interactions and solvent dependent nonlinear optical studies of Sulfadiazine-Ortho-Vanillin Schiff base: (*E*)-4-((2-hydroxy-3-methoxy-benzylidene)amino)-*N*-(pyrimidin-2-yl)benzene-sulfonamide. *Journal of Molecular Structure*. 2018;1161:66–75. Available:<https://doi.org/10.1016/j.molstruc.2018.02.043>
- Neacșu VA, Maxim C, Mădălan AM, Hillebrand M, González-Arellano C, Soriano S, Rentschler E, Andruh M. New complexes of Ni(II) and Co(III) with a Schiff-base ligand derived from *o*-vanillin. Crystal structure magnetic and catalytic properties of a dissymmetric binuclear nickel(II) complex. *Polyhedron*. 2018;150:77–82. Available:<https://doi.org/10.1016/j.poly.2018.05.007>
- Dostani M, Kianfar AH, Mahmood WAK, Dinari M, Farrokhpour H, Sabzalian MR, Abyar F, Azarian MH. An experimental and theoretical study on the interaction of DNA and BSA with novel Ni<sup>2+</sup> Cu<sup>2+</sup> and VO<sub>2</sub><sup>+</sup> complexes derived from vanillin bidentate Schiff base ligand. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*. 2017;180:144–153. Available:<https://doi.org/10.1016/j.saa.2017.02.047>
- Tsantis ST, Lada ZG, Tzimopoulos DI, Bekiari V, Psycharis V, Raptopoulou CP, Perlepes SP. Two different coordination modes of the Schiff base derived from ortho-vanillin and 2-(2-aminomethyl)pyridine in a mononuclear uranyl complex. *Heliyon*. 2022;8(6): . Available:<https://doi.org/10.1016/j.heliyon.2022.e09705>
- Nair MS, Joseyphus RS. Synthesis and characterization of Co(II) Ni(II) Cu(II) and Zn(II) complexes of tridentate Schiff base derived from vanillin and di- $\alpha$ -aminobutyric acid. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*. 2008;70(4):749–753. Available:<https://doi.org/10.1016/j.saa.2007.09.006>
- Salomanravi A, Muthuselvan P, Paularokiadoss F, Jeyakumar TC. Synthesis structure DNA/BSA binding antibacterial and molecular docking studies of tetradentate ONNO Schiff base metal complexes. *Journal of Molecular Structure*. 2023;1287:135570. Available:<https://doi.org/10.1016/j.molstruc.2023.135570>
- Bahaffi SO, Aziz AAA, El-Naggar MM. Synthesis spectral characterization DNA binding ability and antibacterial screening of copper(II) complexes of symmetrical

- NOON tetradentate Schiff bases bearing different bridges. *Journal of Molecular Structure*. 2012;1020:188–196. Available: <https://doi.org/10.1016/j.molstruc.2012.04.017>
9. Nica S, Pohlmann A, Plass W. Vanadium(V) Oxoperoxo Complexes with Side Chain Substituted N-Salicylidenehydrazides: Modeling Supramolecular Interactions in Vanadium Haloperoxidases. *European Journal of Inorganic Chemistry*. 2005;2005(11):2032–2036. Available: <https://doi.org/10.1002/ejic.200401060>
  10. Yousef TA, El-Reash GMA, Rakha TH, El-Ayaan U. First row transition metal complexes of (E)-2-(2-(2-hydroxybenzylidene)hydrazinyl)-2-oxo-N-phenylacetamide complexes. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*. 2011;83(1):271–278. Available: <https://doi.org/10.1016/j.saa.2011.08.030>
  11. Yousef TA, Rakha TH, Ayaan UE, Reash GMAE. Synthesis spectroscopic characterization and thermal behavior of metal complexes formed with (Z)-2-oxo-2-(2-(2-oxoindolin-3-ylidene)hydrazinyl)-N-phenylacetamide (H<sub>2</sub>O). *Journal of Molecular Structure*. 2012;1007:146–157. Available: <https://doi.org/10.1016/j.molstruc.2011.10.036>
  12. Yousef TA, Abu El-Reash GM, Attia MI, El-Tabai MN. Comparative ligational, optical band gap and biological studies on Cr(III) and Fe(III) complexes of hydrazones derived from 2-hydrazinyl-2-oxo-N-phenylacetamide with both vanillin and O-vanillin. *Chemical Physics Letters*. 2015;636:180–192. Available: <https://doi.org/10.1016/j.cplett.2015.07.001>
  13. Hegab MI, Hassan NA, El-Telbani EM, Farag ISA, Abdel-Megeid FME. Synthesis of hindered hydrazones and their reaction with thionyl chloride. *Heteroatom Chemistry*. 2003;14: 223–228. Available: <https://doi.org/10.1002/hc.10125>
  14. Yousef TA, El-Reash GMA, El-Tabai MN. Comparative studies on p-vanillin and o-vanillin of 2-hydrazinyl-2-oxo-N-phenylacetamide and their Mn(II) and Co(II) complexes. *Journal of Molecular Structure*. 2018;1159:246–258. Available: <https://doi.org/10.1016/j.molstruc.2018.01.003>
  15. Kumar SN, Nair HR, Kumar BP. Comparative analysis of anti-oxidant potential of vanillin and ferulic acid in vitro. *Food and Humanity*. 2023;1:1206–1212. Available: <https://doi.org/10.1016/j.foohum.2023.09.014>
  16. Zhu Z, Yu Q, Li H, Han F, Guo Q, Sun H, Zhao H, Tu Z, Liu Z, Zhu C, Li B. Vanillin-based functionalization strategy to construct multifunctional microspheres for treating inflammation and regenerating intervertebral disc. *Bioactive Materials*. 2023;28:167–182. Available: <https://doi.org/10.1016/j.bioactmat.2023.05.005>
  17. Kumar KMP, Kumar BCV, Kumar MNS, Kumar PR, Devaraju S, Butcher RJ, Revanasiddappa HD. Synthesis structural characterization CT-DNA interaction study and antithrombotic activity of new ortho-vanillin-based chiral (SeNO) donor ligands and their Pd complexes. *Inorganica Chimica Acta*. 2021;528:120609. Available: <https://doi.org/10.1016/j.ica.2021.120609>
  18. Yuldasheva N, Acikyildiz N, Akyuz M, Yabo-Dambagi L, Aydin T, Cakir A, Kazaz C. The Synthesis of Schiff bases and new secondary amine derivatives of p-vanillin and evaluation of their neuroprotective antidiabetic antidepressant and antioxidant potentials. *Journal of Molecular Structure*. 2022;1270:133883. Available: <https://doi.org/10.1016/j.molstruc.2022.133883>
  19. Schmitt JL, Stadler AM, Kyritsakas N, Lehn JM. Helicity-Encoded Molecular Strands: Efficient Access by the Hydrazone Route and Structural Features. *Helvetica Chimica Acta*. 2003;86: 1598–1624. Available: <https://doi.org/10.1002/hlca.200390137>
  20. Mezzina E, Spinelli D, Lamartina L, Buscemi S, Frenna V, Macaluso G. An Analysis of <sup>1</sup>H, <sup>13</sup>C and <sup>15</sup>N NMR Substituent Chemical Shifts in para- and meta-Substituted (Z)-Phenylhydrazones of 3-Benzoyl-5-phenyl-1,2,4-oxadiazole. *European Journal of Organic Chemistry*. 2002: 203–208. Available: [https://doi.org/10.1002/1099-0690\(20021\)2002:1<203::AID-EJOC203>3.0.CO;2-N](https://doi.org/10.1002/1099-0690(20021)2002:1<203::AID-EJOC203>3.0.CO;2-N)

21. Sheldrick GM. SHELXT–Integrated space-group and crystal-structure determination. *Acta Crystallographica Section A*. 2015; 71(1):3–8.  
Available: <https://doi.org/10.1107/S2053273314026370>
22. Sheldrick GM. Crystal structure refinement with SHELXL. *Acta Crystallographica Section C*. 2015;71(1):3–8.  
Available: <https://doi.org/10.1107/S2053229614024218>
23. Farrugia LJ. WinGX and ORTEP for Windows: an update. *Journal of Applied Crystallography*. 2012;45(4):849–854.  
Available: <https://doi.org/10.1107/S0021889812029111>
24. Aidi M, Keypour H, Shooshtari A, Mahmoudabadi M, Bayat M, Ahmadvand Z, Karamian R, Asadbegy M, Tavatli S, Gable RW. Synthesis of two new symmetrical macrocyclic Schiff base ligands containing homopiperazine moiety and their mononuclear complexes: Spectral characterization X-ray crystal structural antibacterial activities antioxidant effects and theoretical studies. *Polyhedron*. 2019;167:93–102.  
Available: <https://doi.org/10.1016/j.poly.2019.02.030>
25. Arici K, Altinoz DE, Cavusoglu M, Diken S. Crystal structure IR and NMR spectra of (E)-2-methoxy-4-(2-morpholinovinyl)phenol molecule and its DFT calculations. *Journal of Molecular Structure*. 2023;1275: 134669.  
Available: <https://doi.org/10.1016/j.molstruc.2022.134669>
26. Tamboura FB, Diouf O, Barry AH, Gaye M, Sall AS. Dinuclear lanthanide(III) complexes with large-bite Schiff bases derived from 2,6-diformyl-4-chlorophenol and hydrazides: Synthesis structural characterization and spectroscopic studies. *Polyhedron*. 2012;43(1):97–103.  
Available: <https://doi.org/10.1016/j.poly.2012.06.025>
27. Seck TM, Faye FD, Gaye AA, Thiam IE, Diouf O, Gaye M, Retailleau P. Synthesis of mono and bis-substituted asymmetrical compounds (1-(pyridin-2-yl)ethylidene)carbonohydrazide and 1-(2'-hydroxybenzylidene)-5-(1'-pyridylethylidene)carbonohydrazone: Structural characterization and antioxidant activity study. *European Journal of Chemistry*. 2020;11(4):285–290  
Available: <https://doi.org/10.5155/eurjchem.11.4.285-290.2023>
28. Yeap G.-Y, Ha S.-T, Ishizawa N, Suda K, Boey P.-L, Mahmood WAK. Synthesis crystal structure and spectroscopic study of para substituted 2-hydroxy-3-methoxybenzalideneanilines. *Journal of Molecular Structure*. 2023;658(1):87–99.  
Available: [https://doi.org/10.1016/S0022-2860\(03\)00453-8](https://doi.org/10.1016/S0022-2860(03)00453-8)
29. Ünver H, Yıldız M, Özay H, & Durlu TN. Spectroscopic study and structure of (E)-2-[(2-chlorobenzylimino)methyl]methoxyphenol. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*. 2009;74(5): 1095–1099.  
Available: <https://doi.org/10.1016/j.saa.2009.09.014>

© 2023 Traoré et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

*Peer-review history:*  
The peer review history for this paper can be accessed here:  
<https://www.sdiarticle5.com/review-history/110477>