

Synthesis, Structural Characterization, and Comparative Biological Study of Three New Schiff Bases Derived from Diamines

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Abstract

This paper focuses on the synthesis, structural characterization, and biological activity evaluation of three new Schiff bases: *N,N'*-bis(4-nitrophenylmethylene)benzene-1,3-diamine (compound 4-BD), *N,N'*-bis(4-nitrophenylmethylene)cyclohexane-1,2-diamine (compound 4-CD), and *N,N'*-bis(4-nitrophenylmethylene)hexane-1,6-diamine (compound 4-HD). They were obtained respectively by condensation reaction of metaphenylenediamine, cyclohexane-1,2-diamine, and hexane-1,6-diamine with 4-nitrobenzaldehyde. The structural characterization of these compounds was carried out using standard spectroscopy techniques such as ¹H and ¹³C NMR, infrared spectroscopy (IR), and mass spectrometry, which confirmed the expected structures. Biological activity evaluation through antimicrobial and antioxidant tests showed that compound 4-BD possesses significant antibacterial activity against *Staphylococcus aureus* (MIC of 48.87 (μg/mL)), moderate activity against *S. aureus* sensible, but remains inactive against *Escherichia coli*, *Pseudomonas aeruginosa*, and *Candida albicans*. It also shows significant antioxidant activity (71.559), much more pronounced than its tested structural homologs. Indeed, compound 4-CD possesses an antibacterial activity of 187.5 μg/mL and an inhibition capacity of 15.521. Regarding compound 4-HD, we have an antibacterial activity of 375 μg/mL and an antiradical activity of 14.507. These observations highlight the importance of the presence of a central aromatic group in this specific case for the biological properties of Schiff bases. Opportunities are emerging for the synthesis of a wider range of analogous compounds, to better understand

structure-activity relationships and to optimize their pharmacological applications.

Keywords

Schiff Base, Spectrometry, Antibacterial Activity, Antioxidant Activity

1. Introduction

Schiff bases represent a very interesting class of ligands, as they contain a variety of donor atoms, such as nitrogen, oxygen, and sulfur. They result from condensation reaction products of primary amines with carbonyl compounds [1] [2]. A common structural feature of these compounds is the azomethine group with the general formula $R_1HC = N-R_2$, where R_1 and R_2 are alkyl, aryl, cycloalkyl, or heterocyclic groups. Biologically active Schiff bases (BDSs) can be synthesized using simple procedures with very good yields. Therefore, a wide variety of these bases can be prepared. The imine group present in such compounds has proven essential to their biological activities [3]-[5]. Given the diversity of their applications and the relative stability of their complexes with the majority of transition metals, this category of chemical compounds presents very varied potential interests in many areas, particularly in biological systems, where they have been used as bactericides, fungicides, anticancer agents, antituberculosis agents, anti-inflammatories, antivirals, and anti-HIV agents, and in the treatment of several incurable diseases [6]-[10]. In recent years, researchers have placed great importance on the synthesis and characterization of Schiff base ligands and, like several authors [11]-[14], our systematic research on BDS has enabled us to synthesize many diimines.

Thus, this document deals with the synthesis, characterization, and biological studies of synthesized compounds shown in **Figure 1**.

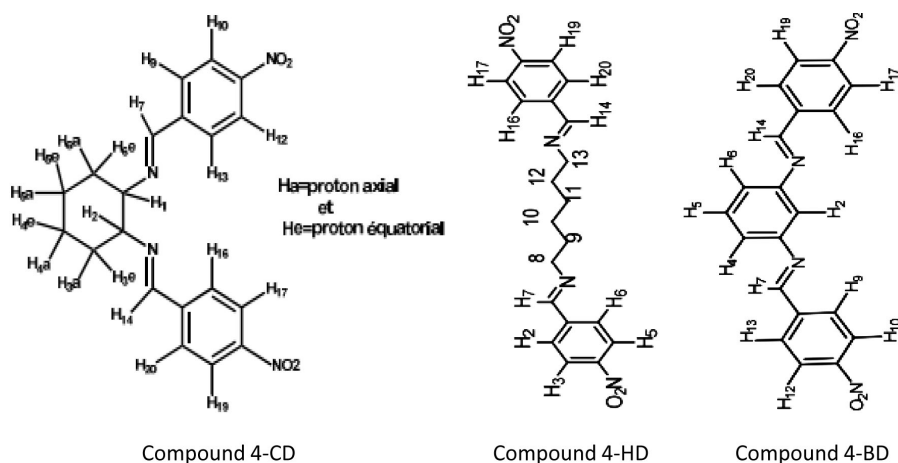


Figure 1. Condensed molecular structure of the symmetrical Schiff bases synthesized with atomic numbering.

1.1. Chemistry

Synthesis of the title compounds was accomplished as outlined in **Figure 2**.

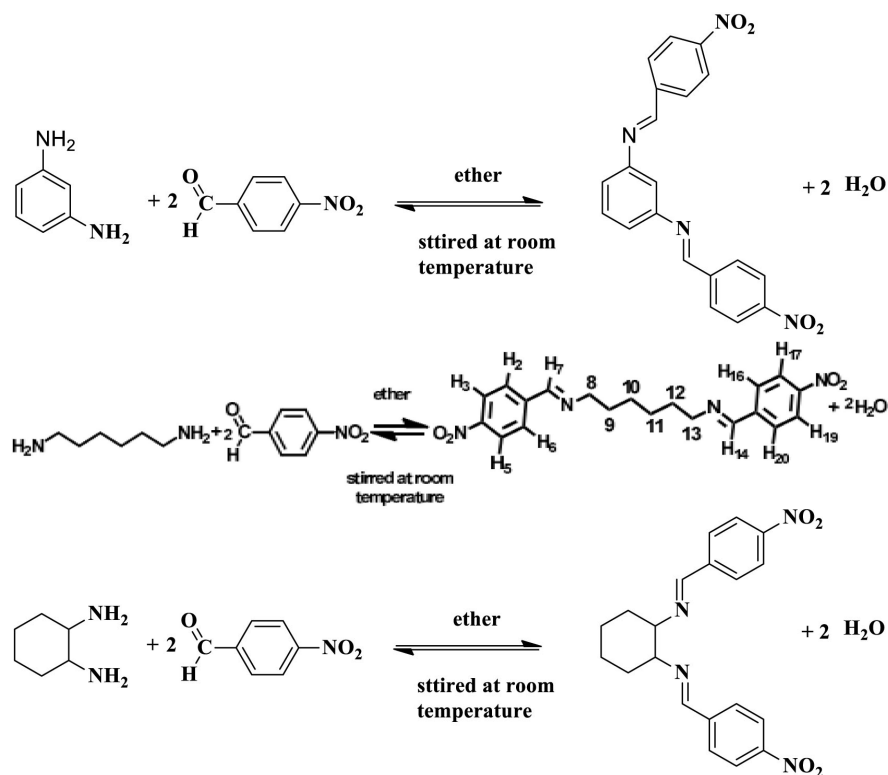


Figure 2. Way of general synthesis of compounds.

1.2. Experimental Protocols

All of the chemicals used in the synthesis were purchased from Sigma-Aldrich and were used as such. Thin layer chromatography was used to monitor the progress of the reactions. Melting points were determined in capillary tube using an MPD Mitamura Riken Kogyo (Japan) electrothermal melting point apparatus and are uncorrected. IR spectra in the range $4000 - 400 \text{ cm}^{-1}$ were obtained on a Bruker-Vector FTIR spectrophotometer, with samples investigated as thin film from CDCl_3 solution. ^1H NMR spectra were recorded on a Bruker-Avance-300 spectrometer, operating at 300 MHz. Mass spectra were recorded on a TOF LCT Premier (WATERS) spectrometer coupled to an HPLC Alliance 2695 chain.

2. Synthesis and Characterization of Compounds

2.1. Synthesis and Characterization of *N,N'*-bis(4-nitrophenylmethylene)hexane-1,6-diamine

4-nitrobenzaldehyde (0.8 mmol) and hexane-1,6-diamine (0.4 mmol) were dissolved in ether (30 ml). At room temperature, the mixture was stirred for three days to give a white precipitate. The precipitate obtained was filtered and recrystallized in methanol. Rf: 0.81 in hexane/acetone (50:50), yield: 86.26%; IR (thin

film from CDCl_3 solution, cm^{-1}): 2853; 2819; 1643; 1535; 850; ^1H NMR (300 MHz, MeOD): 8.50 (s, 2H), 7.98-8.30 (m, 8H), 1.39-3.64 (m, 12H); ^{13}C NMR (75 MHz, MeOD): 155.92, 146.44, 139.27, 126.14, 129.06, 121.33, 59.33, 28.12, 24.65; ESI-HR-MS: peak at m/z 383.1741 $[\text{M} + \text{H}]^+$ corresponding to $\text{C}_{20}\text{H}_{22}\text{N}_4\text{O}_4$.

2.2. Synthesis and Characterization of *N,N'*-bis(4-nitrophenylmethylene)benzene-1,3-diamine

In a 250 mL flask, 0.8 mmol of 4-nitrobenzaldehyde and 0.4 mmol of benzene-1,3-diamine were introduced in 30 mL of ether. At room temperature, the mixture was stirred for three days to give a burgundy-red precipitate. The resulting precipitate was washed and recrystallized in ethanol Rf: 0.74 in benzene/acetone (50; 50), yield: 80.25%; IR (Thin film from CDCl_3 solution, cm^{-1}): 2987; 2903; 1660; 1550; ^1H NMR (300 MHz, DMSO): 8.90 (s, 2H), 7.30 (dd, 2H), 7.53 (dd, 1H), 7.35 (t, 1H), 8.25 (m, 8H); ^{13}C NMR (75 MHz, DMSO): 159.67, 151.63, 148.93, 141.40, 130.16, 129.73, 124.07, 120.13, 113.44; ESI-HR-MS: peak at m/z 383.1741 $[\text{M} + \text{H}]^+$ corresponding to $\text{C}_{20}\text{H}_{20}\text{N}_4\text{O}_4$.

2.3. Synthesis and Characterization of *N,N'*-bis(4-nitrophenylmethylene)cyclohexane-1,2-diamine

4-Nitrobenzaldehyde (0.8 mmol) and cyclohexane-1,2-diamine (0.4 mmol) were dissolved in diethyl ether (30 mL). At room temperature, the mixture was stirred for three days to give a pale yellow precipitate. The resulting precipitate was filtered, washed, and recrystallized in ethanol. Rf: 0.75 in hexane/acetone (50:50), yield: 83%; IR (Thin film from CDCl_3 solution, cm^{-1}): 2939; 2851; 1642; ^1H NMR (300 MHz, CDCl_3): 8.46 (s, 2H), 8.15 (d, 4H), 7.85 (d, 4H), 3.69 (m, 1H), 3.52 (m, 1H), 1.78 (m, 2H), 1.50 (m, 2H), 2.05 (m, 2H), 1.63 (m, 2H); ^{13}C NMR (75 MHz, CDCl_3): 158.57; 148.9; 141.60; 130.5; 124.25; 74.01; 30.89; 24.22; ESI-HR-MS: peak at m/z 381.1522 $[\text{M} + \text{H}]^+$ corresponding to $\text{C}_{20}\text{H}_{20}\text{N}_4\text{O}_4$.

3. Biological Activities

3.1. Antibacterial and Antifungal Activity

We evaluated the antimicrobial activity of our tested compounds on seven microbial strains, and bacteriological tests were carried out at the laboratory of the Swiss Center for Scientific Research (CSRS) in Abidjan.

3.2. Preparation of Pure Compound and Control Antibiotic Solutions

Stock solutions of the compound to be tested were prepared in dimethyl sulfoxide (DMSO) at a concentration of 30 mg/mL. These solutions were then diluted to a concentration of 1500 $\mu\text{g/mL}$ to form stock solutions, which were stored in a refrigerator at 4°C until use.

Furthermore, a stock solution of the control antibiotics was prepared at a concentration of 1 mg/mL from gentamicin and tetracycline powders. This solution

was then diluted to obtain a final concentration of 25 µg/mL, used as a positive control in the antimicrobial activity tests.

3.3. Preparation of the Bacterial Inoculum

After 18 hours of incubation, a well-isolated bacterial colony was collected using a Pasteur pipette and suspended in a tube containing 10 mL of sterile distilled water. Subsequently, 5 to 6 drops of this pre-culture were transferred to a second tube also containing 10 mL of distilled water to obtain the appropriate dilution. This suspension allows for a concentration estimated at approximately 10^6 CFU/mL, corresponding to standard inoculation conditions. This suspension constitutes the bacterial inoculum used for the tests, corresponding to a 1:100 dilution [15].

3.4. Molecules to Be Evaluated on Bacterial Strains

Our compounds evaluated for their antimicrobial activity were dissolved in DMSO to prepare stock solutions at an initial concentration of 30 mg/mL. The solutions were then diluted to 1500 µg/mL and stored at 4°C until use in microbiological testing.

3.5. Evaluation of Bacterial Strain Sensitivity

To determine the activity of the pure compounds against the tested microbial strains, the well diffusion method on agar was used, in accordance with the protocols described by Bakkiyaraj and Pandiyaraj (2011) [16].

This method allowed us to screen the antibacterial activity of our pure compounds using a standardized device.

Petri dishes containing nutrient agar (or Sabouraud agar for *Candida albicans*) were surface-inoculated with bacterial inoculum standardized to 10^6 CFU/mL.

Six-mm diameter wells were then made in the agar using a sterile punch and filled with a precise volume of the solution of the compound to be tested. The plates were incubated at 37°C for 18 to 24 hours for bacteria and at 30°C for yeasts.

Antimicrobial activity was assessed by measuring the diameter of the microbial growth inhibition zone around the wells, compared to those obtained with the control antibiotics (gentamicin and tetracycline at 25 µg/mL).

3.5.1. Principle

This method relies on the diffusion of the antimicrobial product in a solid medium (agar) contained in a Petri dish. After a certain contact time, a concentration gradient forms around the well containing the compound to be tested. The product gradually diffuses through the agar, interacting with the target microorganism inoculated onto the surface of the medium.

The efficacy of an antimicrobial compound is assessed by formation of a zone of microbial growth inhibition around the well. The diameter of this zone (expressed in millimeters) is measured after incubation and determines susceptibility of the microbial strain to the tested compound. Based on the size of this zone, the strain is classified as resistant, susceptible, highly susceptible, or extremely susceptible.

3.5.2. Experimental Protocol

Petri dishes containing Mueller-Hinton agar were used for antibacterial assays. Each dish was uniformly flood-inoculated with a suspension of microbial inoculum diluted 1:100 (approximately 10^6 CFU/mL). After a few moments, the excess suspension was removed using a Pasteur pipette fitted with a bulb, and inoculated plates were left to dry at room temperature for 15 minutes. Under sterile conditions, wells were then made in the agar using a Pasteur pipette. A 50 μ L sample of each substance to be tested was added to each well. The plates were incubated at 37°C for 18 hours for bacterial strains in an incubator. This procedure was repeated three times to ensure reproducibility of the results. Gentamicin (25 μ g/mL) was used as a positive control for bacteria, while amphotericin B was used for fungal strains (*Candida albicans*).

The results were read by measuring the diameter of the inhibition zone (in millimeters) around each well using a ruler. The results are expressed as the size of this inhibition zone [17].

In accordance with the criteria defined by Ponce *et al.* (2003) [17], the interpretation of the results is based on the following classification:

Non-sensitive or resistant: diameter < 8 mm.

Sensitive: 9 mm $\leq$ diameter $\leq$ 14 mm.

Very sensitive: 15 mm $\leq$ diameter $\leq$ 19 mm.

Extremely sensitive: diameter > 20 mm.

3.6. Determination of Minimum Inhibitory Concentrations (MICs)

For MIC determination, the inoculum is prepared by taking 0.3 mL of an 18-hour culture of *Staphylococcus aureus* in broth and subculturing it in 10 mL of Mueller-Hinton broth. These new suspensions are incubated at 37°C for 3 to 5 hours, until slight opalescence appears, equivalent to an optical density of 0.5 on the MacFarland scale. For the final inoculum, 1 mL of these cultures is added to 10 mL of Mueller-Hinton broth [18].

Each microplate contains 96 wells arranged in 8 rows of 12 columns each. The first and second columns of each microplate contain 100 μ L of broth; these are used to monitor for potential contamination of the culture medium. The third column, containing 50 μ L of broth, was used after inoculation to monitor the quality and growth of the bacterial strain. It is unaffected by the dilution of the pure compounds. The following 8 columns receive 50 μ L of broth. The twelfth column is reserved for the pure compounds and the control antibiotics (gentamicin and tetracycline). For each pure compound (1500 μ g/mL) and each antibiotic (25 μ g/mL), 100 μ L of solution are loaded in a double row. Next, using a precision multipipette, successive dilutions are performed applying a geometric progression with a ratio of 2, starting from the column containing the solutions to be tested. Finally, 50 μ L of the inoculum are added to the contents of each well from the third to the twelfth column. The final volume (culture medium, inoculum and drugs) of all wells is 100 μ L. The number of bacteria is estimated at $5 \cdot 10^4$ per well, except in the first two columns, which were not inoculated. The experiment was repeated twice for

each pure compound. The microplates were incubated at 37°C for 18 hours, followed by a visual reading of 100 µL. The bacterial count was estimated at 5×10^4 per well, except in the first two columns, which were not inoculated. The experiment was repeated twice for each pure compound. The microplates were incubated at 37°C for 18 hours, followed by a visual reading.

3.7. Protocols for Antioxidant Activity Tests

3.7.1. Test with DiPhenyl-1-Picrylhydrazyl (DPPH)

2,2-diphenyl-1-picrylhydrazyl was one of the first free radicals used to study the structure-antioxidant activity relationship of phenolic compounds [19]-[21].

3.7.2. Principle

Reduction of free radical DPPH by an antioxidant can be followed by UV-Visible spectrometry, by measuring the decrease in absorbance at 517 nm caused by antioxidants [22]. In the presence of free radical traps, purple-colored DPPH is reduced to yellow 2,2-diphenyl-1-picrylhydrazine [23].

3.7.3. Dosage

DPPH radical trapping activity was measured according to the protocol described by Lopes-Lutz *et al.* [24] and Athamena *et al.* [22] 100 µL of each methanolic solution of the pure compound at different concentrations (3.125 - 100 mg/mL) was added to 2.5 mL of methanolic solution of DPPH (0.025 g/L). In parallel, a negative control was prepared by mixing 100 µL of methanol with 2.5 mL of methanolic solution of DPPH. Absorbance reading was made against a blank prepared for each concentration at 517 nm after 30 minutes of incubation in the dark and at room temperature. Positive control was represented by a solution of a standard antioxidant, ascorbic acid, whose absorbance was measured under the same conditions as the samples and for each concentration [25].

The results were expressed in inhibition percentages (I%) of free radicals using the following formula:

$$I\% = [(Abs \text{ of con neg} - Abs \text{ sample}) / Abs \text{ of con neg}] \times 100$$

I%: Percentage of DPPH inhibition.

Abs Sample: Absorbance of the sample.

Abs of con neg: Absorbance of the negative control.

3.7.4. Statistical Analysis of the Results

For data analysis, STATISTICA 7.1 software [26].

-. was used. The influence of the activities of the different compounds was studied by comparing means using one-way analysis of variance (ANOVA).

When there is a significant difference between activities, multiple comparisons are performed using the smallest significant difference (SSD) test. This test allows us to identify the compound(s) that differ from each other. The significance of the test is determined by comparing the probability P associated with the Fisher F -test statistic at the theoretical threshold $\alpha = 5\%$ [27].

Thus, when $P > 5\%$, we conclude that there is no significant difference between

the means, and when $P < 5\%$, there is a significant difference between the means.

The P values are read from a reference table after calculating the chi-square (χ^2) value. $\chi^2 = \sum((o - e)^2/e)$, where “o” corresponds to observed or actual data, while “e” corresponds to expected or theoretical data.

4. Results and Discussion

Results of antibacterial screening of compounds are presented in **Table 1**. Antibacterial screening of compounds **4-BD**, **4-CD**, and **4-HD** at a concentration of 1500 $\mu\text{g/mL}$ against *Staphylococcus aureus* (CIP) 4.83 and *Staphylococcus aureus* sensitive to penicillin has been found. Antibacterial activity (**Table 1**) of compound **4-BD** is strongly manifested against *Staphylococcus aureus* (CIP) 4.83 and *S. aureus* sensitive, with a zone of inhibition diameter of 10 mm, with an MIC of 48.87 ($\mu\text{g/mL}$) concerning *Staphylococcus aureus* (CIP) 4.83.

However, no activity was observed against *Escherichia coli* (CIP 54127AF), *Pseudomonas aeruginosa* (CIP 103467), and *Staphylococcus aureus* (ATCC 25923).

Similarly, these **4-HD** and **4-CD** homologs are also sensitive against *Staphylococcus aureus* (CIP) 4,83 and *S. aureus* Sensitive (only for **4-CD**), with inhibition zone diameters between 10 and 18 mm, with MICs of 375 ($\mu\text{g/mL}$) and 187.5 ($\mu\text{g/mL}$), respectively, for *Staphylococcus aureus* (CIP) 4,83. No activity was observed on the other strains. Based on these results, it appears that compound **4-BD**, possessing a central benzene ring, is the most active. Gentamicin and tetracycline showed activity on all strains, with an MIC of 0.78 and 0.0976 $\mu\text{g/mL}$, respectively, on *Staphylococcus aureus* (CIP) 4.83.

Comparisons with standard antibiotics such as gentamicin and tetracycline, having MICs of 0.7800 and 0.0976 $\mu\text{g/mL}$, respectively, against *S. aureus* (CIP) 4.83, have put the effectiveness of synthesized compounds into perspective.

Table 1. Average diameters (mm) of inhibition zones and minimum inhibitory concentration (MIC) values of compounds for antibacterial activity.

Measurement of inhibition diameters (mm)										Value of MICs (µg/mL)		
Strains tested	<i>P. aeruginosa</i> CIP	<i>S. aureus</i> CIP	<i>S. aureus</i> Sensible	<i>E. coli</i> CIP	<i>S. aureus</i> ATTC	<i>S. aureus</i> CIP	<i>S. aureus</i> Sensible					
Compounds	Concentrations (µg/mL) C1 = 1500; C2 = 250; C3 = 25											
	C1	C2	C1	C2	C1	C2	C1	C2	C1	C2		
4-CD	0	0	18	10	11	0	0	0	0	0	187.5	>1500
4-HD	0	0	16	10	0	0	0	0	0	0	375	-
4-BD	0	0	10	0	10	0	0	0	0	0	48.87	-
Witnesses	C3	C3	C3	C3	C3	C3	C3	C3	C3	C3		
Gen.	23	10	29	23	32	23	12	0	19	10	0.78	12.5
Tetra.	0	0	36	29	27	19	29	17	24	15	0.0976	12.5

The values are averages of three repetitions; Gen: Gentamicine; Tetra.: tétracycline; *S. aureus* Sensible: *Staphylococcus aureus* sensible à la pénicilline; *S. aureus*: *Staphylococcus aureus*; *P. aeruginosa*: *Pseudomonas aeruginosa*; *E. coli*: *Escherichia coli*.

Antifungal tests performed show that compounds 4-BD and 4-HD are moderately active on *Candida Glabatra* strain with an inhibition diameter of 11 mm, for a MIC greater than 1500 µg/mL. However, all compounds are inactive against *C. albicans* CIP. Results are recorded in **Table 2**. The 4-HD compound has antifungal activity similar to 4-BD. As for the 4-CD compound, it is insensitive to all fungal strains.

Table 2. Average diameters (mm) of inhibition zones and minimum inhibitory concentration (MIC) values of compounds for antifungal activity.

Strains tested	Measurement of inhibition diameters (mm)		Value of MICs (µg/mL)	Value of MICs (µg/mL)
	<i>C. albicans</i> CIP	<i>C. glabatra</i>	<i>C. albicans</i> CIP	<i>C. glabatra</i>
Compound	Concentrations (µg/mL) C1 = 1500; C3 = 25			
	C1	C3		
4-CD	0	0	-	-
4-HD	0	11	-	1500
4-BD	0	11		>1500
witnesses	C3	C3		
Ampho. B	0	0	-	-
Nyst.	11	0	50	-

Ampho. B. Amphotericin B; *Nyst.*: Nystatin.

The antioxidant power of the compounds was demonstrated by trapping the DPPH free radical (Assessment of anti-radical activity by the 2,2-diphenyl-1-picrylhydrazyl method).

Statistical analysis in this study gave results recorded in **Table 3**. It is noted that compound 4-BD has significant inhibitory power, which is even beyond that of the reference (vitamin C).

Compared to 4-CD and 4-HD counterparts, the latter exhibit very weak inhibition with limited DPPH reduction, indicating a moderate capacity to neutralize free radicals. Substitution at *para*, in addition to the presence of a third benzene ring, could be the best combination for the manifestation of important activities for this pharmacophore. Solubility or conformation effects may also occur.

Table 3. Percentages of DPPH inhibition by the tested compounds.

Compound	Mean inhibition ± standard deviation
4-CD	15.521 ± 0.183 (*)
4-HD	14.507 ± 6.007 (*)

Continued

4-BD	71.559 ± 5.972 ()
Vitamin C	68.896 ± 7.540 ()
F	34.2852
P	<0.001

Values represent means ± standard deviation, n = 3 (number of trials). Compounds with the same symbol () have activities that are not very different from each other (): Highest activity (): Average activity (): Low activity (*): Very low activity.

5. Conclusions

This work enabled us to synthesize and characterize *N,N'*-bis(4-nitrophenylmethylene)benzene-1,3-diamine, *N,N'*-bis(4-nitrophenylmethylene)cyclohexane-1,2-diamine, and *N,N'*-bis(4-nitrophenylmethylene)hexane-1,6-diamine compounds.

Structural characterization of the molecules in this study was carried out using classical spectrometric methods (NMR, IR, and MS).

Regarding the antimicrobial activity of 4-BD, which has three aromatic rings in its structure, the result shows that this compound has good antibacterial and antifungal activities, but above all, an exceptional antiradical activity higher than that of vitamin C, chosen as a reference. For this type of molecule, this is the first time, to our knowledge, that such significant antioxidant properties have been observed.

Compared to 4-BD, compounds 4-CD and 4-HD, which have only two aromatic rings in their molecular structures, exhibit moderate biological activity.

The complete delocalization of π electrons along the entire structure of the 4-DB molecule, therefore, appears to be a key factor in the biological activity of this series of compounds.

Looking ahead, we plan to synthesize a larger number of Schiff base ligands of this type and then test different molecules at various concentrations on a large number of bacterial and fungal strains.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Raju, S.K., Settu, A., Thiyagarajan, A., Rama, D., Sekar, P. and Kumar, S. (2022) Synthetic Approaches of Medicinally Important Schiff Bases: An Updated Review. *World Journal of Advanced Research and Reviews*, **16**, 838-852. <https://doi.org/10.30574/wjarr.2022.16.3.1394>
- [2] Schiff, H. (1864) Mittheilungen aus dem Universitätslaboratorium in Pisa: Eine neue Reihe organischer Basen. *Justus Liebigs Annalen der Chemie*, **131**, 118-119. <https://doi.org/10.1002/jlac.18641310113>
- [3] Bringmann, G., Dreyer, M., Faber, J.H., Dalsgaard, P.W., Stærk, D., Jaroszewski, J.W., *et al.* (2004) Ancistrotanine C and Related 5,1'- and 7,3'-Coupled Naphthylisoquinoline Alkaloids From *ancistrocladustanzaniensis*. *Journal of Natural Products*, **67**, 743-748. <https://doi.org/10.1021/np0340549>

- [4] Salimon, J., Salih, N., Ibraheem, H. and Yousif, E. (2010) Synthesis of 2-N-Salicylidene-5-(Substituted)-1,3,4-Thiadiazole as Potential Antimicrobial Agents. *Asian Journal of Chemistry*, **22**, 5289-5296.
- [5] Guo, Z., Xing, R., Liu, S., Zhong, Z., Ji, X., Wang, L., *et al.* (2007) Antifungal Properties of Schiff Bases of Chitosan, N-Substituted Chitosan and Quaternized Chitosan. *Carbohydrate Research*, **342**, 1329-1332. <https://doi.org/10.1016/j.carres.2007.04.006>
- [6] Williams, D.R. (1972) Metals, Ligands, and Cancer. *Chemical Reviews*, **72**, 203-213. <https://doi.org/10.1021/cr60277a001>
- [7] Campos, A., Anaconda, J.R. and Campos-Vallette, M.M. (1999) Synthesis and IR Study of a Zinc(II) Complex Containing a Tetradentate Macrocyclic Schiff Base Ligand: Antifungal Properties. *Main Group Metal Chemistry*, **22**, 283-288. <https://doi.org/10.1515/mgmc.1999.22.5.283>
- [8] Kajal, A., Bala, S., Kamboj, S., Sharma, N. and Saini, V. (2013) Schiff Bases: A Versatile Pharmacophore. *Journal of Catalysts*, **2013**, 1-14. <https://doi.org/10.1155/2013/893512>
- [9] Aboul-Fadl, T., Mohammed, F.A. and Hassan, E.A. (2003) Synthesis, Antitubercular Activity and Pharmacokinetic Studies of Some Schiff Bases Derived from 1-Alkylisatin and Isonicotinic Acid Hydrazide (inh). *Archives of Pharmacol Research*, **26**, 778-784. <https://doi.org/10.1007/bf02980020>
- [10] Li, Y., Yang, Z., Zhang, H., Cao, B., Wang, F., Zhang, Y., *et al.* (2003) Artemisinin Derivatives Bearing Mannich Base Group: Synthesis and Antimalarial Activity. *Bioorganic & Medicinal Chemistry*, **11**, 4363-4368. [https://doi.org/10.1016/s0968-0896\(03\)00499-1](https://doi.org/10.1016/s0968-0896(03)00499-1)
- [11] Elmali, A., Kabak, M. and Elerman, Y. (1999) Conformation and Structure of 3-Methoxyphenyl-salicylaldimine. *Journal of Molecular Structure*, **484**, 229-234. [https://doi.org/10.1016/s0022-2860\(98\)00897-7](https://doi.org/10.1016/s0022-2860(98)00897-7)
- [12] Beena, Kumar, D., Bailey, M.A., Parish, T. and Rawat, D.S. (2014) Antibacterial Activity of Adamantyl Substituted Cyclohexane Diamine Derivatives against Methicillin Resistant *Staphylococcus aureus* and *Mycobacterium tuberculosis*. *Chemistry & Biology Interface*, **4**, 11962-11966. <https://doi.org/10.1039/C4RA00224E>
- [13] Özdemir, Ö. (2016) Novel Symmetric Diimine-Schiff Bases and Asymmetric Triimine-Schiff Bases as Chemosensors for the Detection of Various Metal Ions. *Journal of Molecular Structure*, **1125**, 260-271. <https://doi.org/10.1016/j.molstruc.2016.06.074>
- [14] Avadanei, M., Tigoianu, R., Serpa, C., Pina, J. and Cozan, V. (2017) Conformational Aspects of the Photochromic Reactivity of Two N-Salicylidene Aniline Derivatives in a Polymer Matrix. *Journal of Photochemistry and Photobiology A: Chemistry*, **332**, 475-486. <https://doi.org/10.1016/j.jphotochem.2016.09.024>
- [15] Yéo, S.O., Guessennd, K.N., Ouattara, K., Konan, K.F., Djaman, A.J., Dosso, M. and Coulibaly, A. (2014) Triphytochemistry and *in Vitro* Antibacterial ACTIVITY of Root Extracts of *Cochlospermum planchonii* Hook f. ex. Planch (Cochlospermaceae) on Multireristant Strains. *Scholars Academic Journal of Biosciences*, **2**, 663-670.
- [16] Bakkiyaraj, S. and Pandiyaraj, S. (2011) Evaluation of Potential Antimicrobial Activity of Some Medicinal Plants against Common Food-Borne Pathogenic Micro Organism. *International Journal of Pharma and Bio Sciences*, **2**, 484-491.
- [17] Ponce, A.G., Fritz, R., del Valle, C. and Roura, S.I. (2003) Antimicrobial Activity of Essential Oils on the Native Microflora of Organic Swiss Chard. *LWT—Food Science and Technology*, **36**, 679-684. [https://doi.org/10.1016/s0023-6438\(03\)00088-4](https://doi.org/10.1016/s0023-6438(03)00088-4)
- [18] Dosso, M. and Faye Kette, H. (1995) Documents Techniques Antibiotiques, Université Nationale de Côte d'Ivoire, Faculté de Médecine, Département de Microbiologie,

Laboratoire de BactériologieVirologie, Abidjan, 178 p.

- [19] Blois, M.S. (1958) Antioxidant Determinations by the Use of a Stable Free Radical. *Nature*, **181**, 1199-1200. <https://doi.org/10.1038/1811199a0>
- [20] Padmanabhan, P. and Jangle, S.N. (2012) Evaluation of DPPH Radical Scavenging Activity and Reducing Power of Four Selected Medicinal Plants and Their Combinations. *International Journal of Pharmaceutical Sciences and Drug Research*, **4**, 143-146. <https://doi.org/10.25004/ijpsdr.2012.040212>
- [21] Popovici, C., Saykova, I. and Tylkowsk, I.B. (2009) Evaluation de l'activité antioxydant des composés phénoliques par la réactivité avec le radical libre DPPH. *Revue de génie industriel*, **4**, 25-39.
- [22] Athamena, S., Chalhém, I., Kassah-Laouar, A., Laroui, S. and Khebri, S. (2010) Activités antioxydante et antimicrobienne d'extraits de *Cuminum cyminum* L. *Lebanese Science Journal*, **11**, 69-81.
- [23] Maataoui, B.S., Myene, A. and Hilali, S. (2006) Activités antiradicalaires d'extraits de jus de fruits du figuier de barbarie (*Opuntia ficus indica*). *Lebanese Science Journal*, **1**, 3-8.
- [24] Lopes-Lutz, D., Alviano, D.S., Alviano, C.S. and Kolodziejczyk, P.P. (2008) Screening of Chemical Composition, Antimicrobial and Antioxidant Activities of Artemisia Essential Oils. *Phytochemistry*, **69**, 1732-1738. <https://doi.org/10.1016/j.phytochem.2008.02.014>
- [25] Bougandoura, N. and Bendimerad, N. (2013) Evaluation de l'activité antioxydante des extraits aqueux et méthanolique de *Satureja calamintha* ssp. *Nepeta* (L.) Briq. *Nature & Technologie*, **9**, 14-19.
- [26] SAS (1999) SAS/ETS User's Guide, Version 6. 4th Edition, SAS, 501 p.
- [27] Dagnelie, P. (1999) Théories et méthodes statistiques. 2nd Edition, Presse agronomique de Gembloux, 463 p.