Binuclear Cu(II) Schiff base complexes as precursors for the synthesis of CuO nanoparticles: anticancer activity against MCF-7 cell line

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ABSTRACT
Homobinuclear Cu(II) complexes 1 and 2 were synthesized and characterized by elemental analysis, FTIR, 1H NMR, Mass, UV–vis, magnetic moment, ESR and TGA studies. The synthesized complexes 1 and 2 were used as precursors for the synthesis of CuO Nps by calcination method. CuO Nps were characterized by FTIR, XRD, scanning electron microscopy (SEM), and EDX. XRD peaks clearly indicated the monoclinic structure of CuO. CuO nanoparticles were synthesized with average particle size 3–4 and 5–10 nm. The morphologies and size of the obtained products were further investigated by SEM. Presence of essential constituents of CuO Nps was investigated by EDX studies. The Anticancer activity of the precursors 1&2 and its nanoparticles have been analyzed against the MCF-7 cell line by MTT assay. The Precursor 1 with IC50 value 12.66 μM was found to have high anticancer activity than other compounds.

Synopsis:
• Binuclear Cu(II) Schiff base complexes 1 & 2 were synthesized from the ligands L1 and L2, respectively.
• Binuclear Cu(II) complexes were successfully used as a precursor for the synthesis of CuO Nps.
• The ligands, precursors, and the CuO Nps were analyzed for their anticancer activity against the MCF-7 cell line.
• Precursor 1 synthesized from the ligand L1 shows high activity than other compounds due to the presence of the heterocyclic moiety.
1. Introduction

A great deal of work has been carried out on the synthesis and characterization of transition metal complexes with Schiff base ligands, mainly due to their applications in organic chemistry, as liquid crystals and in catalytic processes. The Schiff-base complexes were found to have higher anticancer activity than the free ligands. Complexes with transition metals (such as manganese, copper and nickel) were found to have antibacterial, antifungal, and cytotoxicity activity.[1–4]

Comparing to other metallic species, Copper complexes have proved to be one of the best metallic species that have wide anticancer activity due to the selective permeability of cancer cell membranes to copper compounds.[5] Studies on the biological activities of Cu(II) complexes including DNA binding,[6] DNA cleavage[7] anti-cancer,[8] and anti-microbial activities[9] have been documented extensively in the literature. Cu(II) complexes are considered the best alternative to cis–platin complexes in the scope of anticancer activity mainly due to their biocompatibility and significant functions in biological systems.[10,11]

Nano structure metal oxides have been studied in the field of nanotechnology both from a fundamental and industrial point of view.[12] The recent research in the field of nano-cancer biology has led to the development of smart engineered nanomaterial that could be used for early diagnosis and treatment purpose. Cancer is one of the principal causes of mortality worldwide and represents a serious health problem. When exploring new strategies for the treatment of cancer, one possibility is the use of nanomaterials. In anticancer therapy research, metal oxide NPs are used experimentally to directly kill tumor cells in vitro and in vivo. Studies report the anticancer activity of Copper oxide nanoparticles against A549 human lung cancer cells and MCF-7 breast cancer cells, respectively.[13]

Recently, nanoparticles synthesized from Schiff base transition metal complexes have been reported by researchers. Synthesis of nanoparticles from the Schiff base transition metal complexes was one of the most suitable method, because the products obtained were of good purity and with perfect structure.[14–21] The thermal decomposition of transition metal complexes is one of the simplest and least expensive techniques for preparing nano-sized transition-metal oxides.[22–25] This technique is simple and with no need for a template and complex apparatus. By selecting an appropriate precursor coupled with a rational calcination procedure, products with nano sizes could be obtained. This method also has potential advantages, including high yield of pure products, absence of solvent, and exempting the need for special equipment.

Based on the above facts, herein we have reported the synthesis of CuO nanoparticles from the binuclear Schiff base copper complexes by calcination method and their characterization by various physicochemical methods. The precursors and its nanoparticles were analyzed for their anticancer activity against the MCF-7 cell line by MTT assay.

2. Materials and methods

All chemicals were of analytical reagent grade and were used as received. The elemental analysis was performed on Carlo-Erba 1106 model instrument at CDRI, Lucknow. The molar conductivity measurements were carried out using an Elico-CM Conductivity Bridge with 10−3 M DMSO as solvent. FTIR spectra were recorded as KBr pellet using a Thermo Nicolet, Avatar 370 model FT-IR spectrophotometer ranging between 4000–400 cm−1. Electronic absorption spectra were recorded on a Perkin Elmer Lambda 25 UV–vis spectrometer between 200–800 nm using DMSO solvent. The magnetic properties of the complexes were studied via a Gouy balance. 1HNMR spectra for the ligand were recorded on a Bruker Avance III, 400-MHz NMR spectrometer using DMSO-d 6 solvent and TMS as internal standard. The EPR spectrum was recorded on a Bruker spectrometer operating in the X-band and using 100-kHz magnetic field modulation. The thermogravimetric analysis of the complexes were recorded on a Perkin Elmer STA 6000 thermal analysis system within the temperature range 40–740 °C. The SEM/EDS micrographs were recorded on a JEOL Model JSM – 6390LV microscope.

2.1. Synthesis

2.1.1. Synthesis of ligand (L1)

The binuclear Schiff base ligand L1, was prepared by refluxing a homogeneous mixture of 2,6-diaminopyridine (0.005 mol), urea (0.01 mol), and salicylaldehyde (0.02 mol) in ethanol for about 2 h. The solid product formed was cooled, filtered, washed with ethanol, and dried in a desiccator.

Anal. Calcd. for L1, C20H27N7O4 (%) : C,68.97; H,4.43; N,16.09;O,10.48; Found: C, 68.97; H,4.46; N,16.08;O,10.50; Yield: 90%; color: Brick red color; m.p:195 °C. IR (KBr, cm−1) :1598 ((C=N)); 1630 (υ(CH=N)); 1274 (υ(C–O)); 586 (In-plane bending); 774 (Out-plane bending); UV–vis (λmax, nm): 284,354;

2.1.2. Synthesis of ligand (L2)

The binuclear Schiff base ligand L2, was prepared by refluxing a homogeneous mixture of 4,4’-diaminodiphenylmethane (0.005 mol), urea (0.01 mol) and
salicylaldehyde (0.02 mol) in ethanol for about 2 h. The solid product formed was filtered, washed with ethanol, and dried in a desiccator.

Anal. Calcd. for L2, C_{43}H_{34}N_{6}O_{4} (%) : C, 73.92; H, 4.87; N, 12.03; O, 9.17; Found: C, 72.88; H, 4.76; N, 11.85; O, 9.04; Yield: 90%; color: Yellow color; m.p: 165 °C. IR (KBr, cm\(^{-1}\)) : 1556 (\(\nu(C=N)\)); 1610 (\(\nu(CH=NN)\)); 1279 (\(\nu(C-O)\)); UV–vis (\(\lambda_{max}, nm\)): 336, 366.

2.1.3. Synthesis of precursors 1 and 2 from the corresponding Schiff base Ligands

The homobinuclear presursors 1 and 2 (Figure 1) was synthesized by the reaction of an ethanolic solution of the ligand L1 and ligand L2 (0.002 mol), respectively with Cu(CH\(_3\)COO)\(_2\).H\(_2\)O (0.004 mol). The contents were then refluxed for 3 h and cooled at room temperature. The products formed were filtered, washed with ethanol, and dried in a desiccator.

Anal. Calcd. for 1, Cu\(_2\)O\(_4\)N\(_7\)C\(_{35}\)H\(_{23}\) (%) : C, 57.37 H, 3.14; N, 13.39; O, 8.74; Cu, 17.35; Yield: 85%; color: green; m.p: > 330 °C. IR (KBr, cm\(^{-1}\)) : 1587 (\(\nu(C=N)\)); 1612 (\(\nu(CH=NN)\)); 1325 (\(\nu(C-O)\)); 545 (\(\nu(M-N)\)); 449 (\(\nu(M-O)\)); 581 (In-plane bending); 758 (Out-plane bending); UV–vis (\(\lambda_{max}, nm\)): 280, 350, 384, 418, 591, 702.

Anal. Calcd. for 2, Cu\(_2\)O\(_4\)N\(_6\)C\(_{43}\)H\(_{30}\) (%) : C, 62.84; H, 3.65; N, 10.23; O, 7.79; Cu, 15.47; Yield: 85%; color: Dark green; m.p: > 330 °C. IR (KBr, cm\(^{-1}\)) : 1562 (\(\nu(C=N)\)); 1689 (\(\nu(CH=NN)\)); 1305 (\(\nu(C-O)\)); 516 (\(\nu(M-N)\)); 423 (\(\nu(M-O)\)); UV–vis (\(\lambda_{max}, nm\)): 309, 346, 382, 410, 688, 734.

2.1.4. Preparation of Copper Oxide nanoparticles (CuO)

The CuO nanoparticles was prepared from the precursors 1 and 2 by Calcination method.[26]

The Copper Schiff base complexes were taken in a porcelain crucible and heated to 500 °C in an electric furnace for 2 h. The decomposition product generated from the complexes was cooled to room temperature and kept in desiccator. The pure CuO Np thus obtained was characterized by spectral studies.

2.1.5. In vitro cytotoxic activity

The In vitro cytotoxic activities of the synthesized Schiff bases and their complexes were studied on MCF-7 cell line (human breast cancer cells) by applying the MTT colorimetric assay. MTT assay is a colorimetric assay used for the determination of cell proliferation and cytotoxicity, based on reduction of the yellow colored water soluble tetrazolium dye MTT to formazan crystals. Mitochondrial lactate dehydrogenase produced by live cells reduces MTT to insoluble formazan crystals, which upon dissolution into an appropriate solvent exhibits purple color, the intensity of which is proportional to the number of viable cells and can be measured spectrophotometrically at 570 nm. The cell culture media was gently washed with PBS (Phosphate Buffered Saline) solution and incubated at 37 °C for approximately 2–5 min. The monolayer cells were detached with enough reagent of trysin-EDTA to make single cell suspension and the viable cells were counted using a Haemocytometer. The cells were diluted with a growth medium of 10% FBS, 2% Pecnicillin–Streptomycin solution, 50 μg/ml Gentamycin, and 0.25–2.5 μg/ml Amphobotericin. The cells were then resuspended in the freezing medium containing 40% FBS and 5% DMSO and were placed on wet ice for 24 h. A concentration of 100–200 μL of a cell suspension in a culture medium at a required cell density (25,000–50,000 cells per well) were seeded into 96-well plates and incubated for 24 h. After 24 h, appropriate concentrations (100–500 μL) of the test agents were added to the cells and incubated at 37 °C in a 5% CO\(_2\) atmosphere. After the incubation period, the plates were removed from the incubator and 1% of MTT in Phosphate Buffered Saline (PBS) was added to each well and the plates were wrapped with aluminum foil to avoid exposure to light. The plates were then incubated at 37 °C in CO\(_2\) atmosphere for 4 h. The MTT containing medium was then discarded and the cells were washed with PBS. The MTT formazan crystals formed were dissolved by adding 100 μL of DMSO and this was mixed properly by pipetting up and down. The absorbance of the purple blue formazan dye was measured on a spectrophotometer or
3. Results and discussion

The precursors 1 and 2 synthesized from the Schiff base L1 and L2 have been characterized by the elemental and spectral studies. The low molar conductance values \( \lambda' \) i.e. 11.60–23.80 \( \text{Ω}^{-1} \text{cm}^{2} \text{mol}^{-1} \), show the non-electrolytic nature of the complexes.

3.1. FTIR spectra

In the IR spectra of the ligands the band at 1630 and 1610 cm\(^{-1}\), was assigned to \( \nu(\text{CH}=\text{N}) \) stretching frequency, which was shifted by about 16–20 cm\(^{-1}\) in the complexes indicating the coordination of the azomethine nitrogen to the metal ions.[29] The sharp band observed at 3353 and 3445 cm\(^{-1}\) in the ligands were assigned to the \( \nu(\text{OH}) \). This band was not present in the metal complexes, which indicates the coordination of the phenolic hydroxyl group after deprotonation.[30] The band appeared at 1571 and 1556 cm\(^{-1}\) corresponding to the \( \nu(\text{C}═\text{N}) \) stretching frequency in the free ligands were shifted in the complexes. The band observed at 1282 and 1272 cm\(^{-1}\) corresponding to phenolic \( \nu(\text{C}−\text{O}) \) stretching was shifted to a higher frequency in the complexes. This shift indicates the coordination of the ligand to the metal ion.[29,31]

The new bands appeared at 534–516 and 445–423 cm\(^{-1}\) region in the complexes were assigned to \( \nu(\text{M}−\text{N}) \) and \( \nu(\text{M}−\text{O}) \) respectively, which further confirms the coordination of the ligands to the metal ions.[32]

3.2. Electronic spectra

In the Electronic spectra of the free ligands the bands observed at 284–336 and 354–366 nm were due to the \( \pi\rightarrow\pi^* \) and \( n\rightarrow\pi^* \) transitions respectively, which were shifted to lower wavelengths in the complexes. The new bands observed in the complexes 1 and 2 at 386–382 nm and 422–410 nm were assigned to the \( \text{L}\leftrightarrow\text{M} \) and \( \text{M}\leftrightarrow\text{N} \) transitions, respectively. The two broad bands observed at 591–688 nm and 702–734 nm in the complexes 1 and 2 were attributed to the \( ^2\text{B}_1 \leftrightarrow^2\text{A}_1 \) and \( ^2\text{B}_1 \leftrightarrow^2\text{E}_g \) transitions, respectively, suggest a square planar geometry around each Cu(II) ion.[33]

This was further confirmed by the magnetic moment value of 1.92 B.M. This assignment was in good agreement with the assignments made for the similar copper complexes.[34]

3.3. \(^1\text{H} \) NMR spectra

\(^1\text{H} \) NMR spectra of the Ligand L1 and L2 (Figure 2) which show signals at 10 and 9 ppm, respectively, were assigned to the (HC=N) azomethine proton. The multiplet signal which appeared at 6.5–7.6 and 6.9–7.8 ppm in the ligands was attributed to the aromatic rings. The signals at 13.23 and 13.16 ppm were assigned to the phenolic –OH group.[35]

A singlet which appeared at 2.5 ppm in the ligand L2 was assigned to the methane proton.

![Figure 2. \(^1\text{H} \) NMR spectra of Ligand 1 and Ligand 2.](image_url)
3.4. Mass spectra

The mass spectra of the free ligands L1 and L2 (Figure 3) show molecular ion peaks at $m/z = 609$ and 698 amu, respectively, which correspond to the molecular formula $C_{35}H_{27}O_4N_7$ and $C_{43}H_{34}O_4N_6$. The series of peaks in the mass spectra of the ligands L1 and L2 were assigned to the different fragments of the ligands. By comparing the molecular formula weights of the ligands with their $m/z$, the proposed structure (Figure 1) of the ligands were confirmed.

Figure 3. Mass spectra of (a) Ligand 1 and (b) Ligand 2.
3.6. ESR spectra of precursors 1 and 2

ESR spectra of the complexes 1 and 2 (Figure 5) exhibits signals with g values 2.25–2.32 and 2.05–2.08 corresponds to $g_{||}$ and $g_{\perp}$. The trend $g_{||} = 2.25 > g_{\perp} = 2.05 > 2$ observed for both the copper complexes shows that the unpaired electrons lie in the $d_{x^2-y^2}$ orbital, suggesting a square planar geometry for the complex.[38] The $g_{||}$ values indicate the M–L bond nature. If the $g_{||}$ value is < 2.3, metal to ligand bond will have covalent character and if $g_{||}$ value is > 2.3, metal to ligand bond will have ionic character.[39] According to this statement it follows that the M–L bond in these complexes were in Covalent nature.

The geometric parameter $G$, is calculated using the Hathaway [40] expression, $G = (g_{||} - 2)/(g_{\perp} - 2)$, and if $G > 4$, the exchange interaction is negligible, whereas when $G < 4$, a considerable interaction is indicated in the solid complex. Based on this for the complexes 1 and 2, $G > 4$, which indicates that there is no interaction between the copper ions.

3.5. PXRD of precursors 1 and 2

Powder X-ray diffraction pattern of the precursor 1 shows less intense crystalline peaks, which indicates the non-crystalline nature of the complex, whereas the sharp crystalline peaks of precursor 2 indicates its crystalline phase (Figure 4). The 2θ values for the important peaks of the precursor 2 were listed in Table 1. The presence of forbidden No.7 (Forbidden reflection, i.e. the reflections which actually exists in the crystals that do not show up in diffraction and it occur due to the destructive interference of some reflections) indicates that the precursor 2 may belong to hexagonal (or) tetragonal system. The size of crystallite was calculated using Deby–Scherrer Equation (2),[36,37]

$$D = \frac{K \lambda}{\beta \cos \theta}$$  \hspace{2cm} (2)

where $D$ is the crystallite size, $K$ is a constant (0.94 for Cu grid), $\lambda$ is the X-ray wavelength ($\lambda = 1.5406$ Å), $\theta$ is the Bragg diffraction angle, and $\beta$ is the integral peak width. The crystallite size of the precursor 2 was found to be 6.93 nm.

![Figure 4. PXRD of precursors 1 and 2.](image)

![Figure 5. ESR spectra of precursors 1 and 2.](image)

![Table 1. X-ray Powder Diffraction data Precursor 2.](image)

| Peak | $2\theta$ | $\theta$ | $\sin \theta$ | $\sin^2 \theta$ | $h^2+k^2+l^2$ | $hkl$ | $d_{\text{obs}}$ | $d_{\text{calc}}$ |
|------|----------|---------|--------------|----------------|------------|------|----------------|----------------|
| 1    | 8.490    | 4.245   | 0.074        | 0.005476       | 1          | 100  | 10.4064        | 10.4094        |
| 2    | 9.666    | 4.833   | 0.084        | 0.007056       | 1          | 100  | 9.1432         | 9.1430         |
| 3    | 11.258   | 5.629   | 0.098        | 0.009604       | 2          | 110  | 7.8532         | 7.8538         |
| 4    | 12.771   | 6.3855  | 0.111        | 0.012321       | 2          | 110  | 6.9261         | 6.9396         |
| 5    | 16.404   | 8.202   | 0.142        | 0.020164       | 4          | 200  | 5.3995         | 5.3995         |
| 6    | 18.508   | 9.254   | 0.164        | 0.026896       | 5          | 210  | 4.7900         | 4.6896         |
| 7    | 20.038   | 10.019  | 0.174        | 0.030276       | 6          | 211  | 4.4276         | 4.4277         |
| 8    | 21.978   | 10.989  | 0.190        | 0.0361         | 7          | 221  | 4.0409         | 4.0413         |
| 9    | 22.943   | 11.4715 | 0.199        | 0.039601       | 7          | 221  | 3.8731         | 3.8732         |
| 10   | 24.983   | 12.4915 | 0.216        | 0.046656       | 9          | 221  | 3.5614         | 3.5613         |
| 11   | 25.871   | 12.9355 | 0.224        | 0.050176       | 9          | 221  | 3.4374         | 3.4410         |
| 12   | 15.510   | 7.755   | 0.267        | 0.071289       | 13         | 320  | 2.8805         | 2.8805         |
| 13   | 31.787   | 15.8935 | 0.274        | 0.075076       | 13         | 320  | 2.8126         | 2.8128         |
3.7. Thermo gravimetric Analysis
Thermal analysis of the complexes indicates the thermal stability of the complexes and its thermal decomposition characteristics. Complex 1 decomposes in four steps, whereas the Complex 2 decomposes in three steps (Figure 6). The first step of decomposition corresponds to the loss of lattice water at lower temperature region between 40–160 °C in both the complexes. The remaining three decomposition steps of the complex 1 within the temperature range 160–400 °C with the total mass loss of 72% (calcd. 74%) may be accounted for the decomposition of the ligand moiety leaving the metal oxide as a residue. The remaining two decomposition steps of the complex 2 within the temperature range 170–450 °C with the total mass loss of 73% (calcd. 76%) may be accounted for the decomposition of the ligand moiety leaving the metal oxide as a residue.

3.8. Characterization of CuO NP’s
3.8.1. PXRD
X-ray diffraction (XRD) pattern of the CuO Np’s (Figure 7) shows the diffraction peaks correspond to the reflections from (110), (002), (111), (202), (020), (202), (113), (311), (113), (311), (004). All these peaks were clearly indexed to the monoclinic structured CuO, which are reliable with the standard reported values (JCPDS File No.41-0254). The Crystallite size of Copper oxide nano particles synthesized from the precursors 1 and 2 calculated by the Scherrer Equation (2),[36,37] was found to be 6.3 and 12.96 nm, respectively.

3.8.2. SEM
The SEM images of the synthesized CuO NPs shows a uniform distribution of particle size (Figure 8). The average particle size of Copper oxide nano particles synthesized

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**Figure 5.** EPR spectra of the presursors 1 and 2.

**Figure 6.** TGA of precursor 1 and 2.
Figure 7. PXRD of CuO NPs synthesized from the precursors 1 and 2.

Figure 8. SEM images of CuO NPs synthesized from the precursors 1 and 2.

Figure 9. Histogram of CuO NPs synthesized from precursors 1 and 2.
and 1621 cm\(^{-1}\) was assigned to H-O-H bending vibration of water molecule observed from the air.\cite{41}

3.9. \textit{In vitro} cytotoxic activity of the precursors and its Nanoparticles

\textit{In vitro} Cytotoxic activity of the ligands \textbf{L1, L2, precursors 1, 2} and CuO NPs were evaluated against the MCF-7 cell line (MCF-7).

| Sample                        | IC50 value (μM) |
|-------------------------------|-----------------|
| L1                            | 14.06           |
| L2                            | 50.69           |
| Precursor 1                   | 12.66           |
| CuO Np from precursor 1       | 32.98           |
| Precursor 2                   | 14.87           |
| CuO Np from precursor 2       | 47.34           |
| 5-flourouracil                | 11.24           |

Figure 10. EDAX spectra of the CuO NPs synthesized from precursors 1 and 2.

Figure 11. FTIR spectra of the CuO NPs synthesized from precursors 1 and 2.

Table 2. IC50 values of synthesized compounds against breast cancer cell line (MCF-7).

from the precursors 1 and 2 was found to between 3–4 and 5–10 nm, respectively (Figure 9).

3.8.3. \textit{EDS}

EDS was utilized to determine the elemental compositions of prepared CuO NPs. EDS spectrum of CuO NPs are shown in Figure 10. The spectrum shows only the characteristic peak corresponding to Cu, which indicates the purity of the CuO NPs.

3.8.4. \textit{FTIR}

FTIR spectra of CuO nanoparticles are depicted in Figure 11. The FTIR spectra of both the CuO nps shows CuO vibrations at 567, 529 and 472 cm\(^{-1}\), which indicates the formation of pure CuO Nps. The band observed at 3487 and 3435 cm\(^{-1}\) in the FTIR spectra of the CuO Nps synthesized from the precursor 1 and 2 respectively, indicates O-H stretching vibration and the weak band at 1638 and 1621 cm\(^{-1}\) was assigned to H-O-H bending vibration of water molecule observed from the air.\cite{41}
and the ligands exhibited an inhibitory effect on the proliferation of MCF-7 cell line in a dose-dependent manner. As the concentration of the compounds increases from 10 μg/mL to 50 μg/mL, their cytotoxic activities were observed using the MTT assay. 5-fluorouracil (IC50 = 11.24 μM) was used as a control. The IC50 values of the compounds are depicted in Table 2. The results showed that the complexes and the ligands exhibited an inhibitory effect on the proliferation of MCF-7 cell line in a dose-dependent manner. As the concentration of the compounds increases from 10 μg/mL to 50 μg/mL, their cytotoxic activities were observed using the MTT assay. 5-fluorouracil (IC50 = 11.24 μM) was used as a control. The IC50 values of the compounds are depicted in Table 2. The results showed that the complexes

Figure 12. Cytotoxic activities of compounds against MCF-7 cell line at different concentrations where, (a) & (b) were of Ligand 1 & 2, (c) & (d) were of precursor 1 and its Np and (e) & (f) were of precursor 2 and its Np.
to 50 μg/mL, the cell viability decreases (Figure 12). From the results it was inferred that the anticancer activity of the precursor 1, synthesized from the ligand L1 was higher than that of the other compounds. Thus the complexation of metal ions enhances the anticancer behavior as it is evidenced by the lower IC50 values of the complex compared with the uncoordinated ligands. The enhanced cytotoxic activity of the precursor 1 may be due to the biologically active nature of the ligand L1. According to Tweedy’s chelation theory, the increased activity of the metal complexes may be due to the lipophilic character of the central metal atom. It is also evidenced from the results that as the concentration of the CuO NPs increases the cell viability also increases, which indicates its less anticancer activity.

The increase in activity of the ligand L1 and the precursor 1 may be due to the biologically active nature of the heterocyclic moiety 2,6-diaminopyridine.

Studies show that high doses of drugs may cause side effects. So drugs, which have more activity at low concentrations, are highly preferable.

4. Conclusion

In the present work we have reported the synthesis of binuclear Schiff base ligands L1 & L2 and its Cu(II) complexes. The ligands and its metal complexes were characterized by elemental analysis, molar conductance, FTIR, UV–vis, 1H-NMR, PXRD, EPR, and TGA studies. The Cu(II) complexes were successfully used as a precursor for the synthesis of CuO nanoparticles. The CuO nanoparticles were synthesized with average particle size 3–4 and 5–10 nm respectively, which were confirmed by XRD analysis. The formation of the CuO NPs was further confirmed by SEM and EDX studies. The ligands, Cu(II) complexes, and the CuO NPs were analyzed for their anticancer activity against the MCF-7 cell line by MTT assay. Cu(II) Schiff base complex (precursor 1) synthesized from the ligand L1 was found to be highly active than other compounds due to the presence of the heterocyclic moiety.

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Disclosure statement

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