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pH responsive curcumin/ ZnO nanocomposite for drug delivery

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ABSTRACT

Curcumin is recognized as an important natural biomaterial which has a wide range of biological importance, unfortunately it lacks in bioavailability predominantly due to its poor aqueous solubility. The intention of the present investigation was to develop a novel nanocomposite of curcumin with ZnO nanoparticle in order to improve its aqueous-phase solubility and develop its efficiency on microbes and cancer cells. Therefore, we have constructed an aqueous solvable curcumin/ZnO nanocomposite from the insoluble commercial curcumin and poorly soluble ZnO nanoparticles, consequently enhancing its biological importance. The synthesized ZnO nanoparticles, nanocurcumin and the nanocomposite were analyzed with transmission electron microscope (TEM), and X-ray diffraction (XRD) along with spectral techniques. The calculated average particle size of ZnO nanoparticle and nanocomposite from XRD was found to be 21.44 nm and 24.66 nm respectively. The TEM image reveals that this new nanocomposite was found to have narrow particle size of 53 nm. The observed results declared that the title nanomaterials showed excellent antibacterial activity against, *Escherichia coli*, *Bacillus subtilis*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus*. Their cytotoxicity performance against gastric cancer (AGS) cells was also carried out and observed that they showed concentration dependency. All the observed results declared that it has great potential for antibacterial and anticancer applications.The observed results of this investigation demonstrate that the present nano-conjugate can effectively deliver the antibacterial, anticancer drug curcumin towards the targeted biomolecules and hence appears to be a promising nano-formulation for chemotherapy and other biomedical applications after a series of *in-vivo* tests on animal models.

Keywords: Nanocurcumin; ZnO/curcuminnano composite; antibacterial; anticancer activity.

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Introduction

During the last decade, nanomaterials have attracted considerable interest of researchers and scientists due to the functionalities unavailable to bulk materials. As a new generation of nanomaterials, nanocomposites signify an emerging area in the frontier between the fields of materials science, life science, and nanotechnology **[1]**. Their novel structures exhibit improved physical, chemical and biological properties. Their smaller size and consequent larger surface area than the micro-structured materials provide them with better functionality **[2]**. Nanotechnology is also being utilized in medicine for diagnosis, therapeutic drug discovery and delivery for many diseases and disorders. Metal oxide nanoparticles such as ZnO, MgO, TiO_2, SiO_2, CuO_2 are very good antimicrobial agents. Their selective toxicity towards biological systems suggests their potential applications as

nanomedicines **[3]**. Among many nanostructured metal oxides, ZnO has drawn broad attention due to its wide range of applications such as optics, electronics, cosmetics, food additives, biosensors, **[4]** and drug deliveries **[5]**. ZnO is chemically stable under processing condition, non-toxic, biocompatible, low cost and ecofriendly **[6]**. It is one of the essential minerals for human health as antibiotics by controlling the spread of resisted pathogens in food processing environment **[7]**. In recent years, the structure and size dependent ZnO nanoparticle have drawn much attention for selective toxicity towards cancer cells **[8]**, such as human brain tumor and cervical cancer **[9]**.

Gastric cancer is the second most challenging cause of cancer related death in the world and it remains difficult to cure in Asia and worldwide **[10]**. About 8.6% of causality that occurred in 2002 was gastric cancer. This is high risk in Japan, China, Eastern Europe and Latin America **[11]**. However, this is not a big challenge in South Asian countries particularly India, because of the everyday consumption of turmeric in their food. Among numerous natural dietary compounds exhibiting therapeutic effects with no or minimal side effects to normal organs in cancer treatment, curcumin has received substantial attention. Curcumin is an orange-yellow coloured polyphenolic compound isolated from the herb *Curcuma longa* with anticarcinogenic effects, this compound present in turmeric, plays a major role in various biological functional properties. Extensive research on this compound over the past five decades has well established its excellence in various biological applications. **[12-17]** However, the major disadvantage of curcumin and ZnO Nps is of low aqueous solubility and poor bioavailability. To overcome this disadvantage and make them as more bioavailable materials, biodegradable metal oxide nanocomposites have been of the most interest in drug delivery applications. Various types of nanoparticles, such as polymer NPs, polymeric micelles, liposome/phospholipid, nano/microemulsions, nanogels, solid lipid nanoparticles, polymer conjugates, self-assemblies and metal oxides, are suitable for the delivery of an active form of curcumin to tumors **[12, 18-20]**. In this present work we used ZnO NPs to deliver curcumin as drug to the targeted biomolecules. The major advantage for considering ZnO nanoparticles to use as drug carrier is its inherent preferential *in-vitro* cytotoxicity against cancer cells **[21]**. The biodegradable ZnO nanoparticles can dissolve easily and eventually be converted into ions that can be absorbed by the body and become part of the nutritional cycle, and therefore, they are proposed for *in-vivo* biomedical applications. In this regard, the present work describes the synthesis and characterization of an innovative, efficient, water-soluble nanodrug carrier system containing curcumin and ZnO to deliver curcumin at the targeted tissue. The enhanced antibacterial evaluation and *in-vitro* drug release study of the prepared nanoconjugate was also performed. The effect of curcumin-loaded nanocomposite on AGS cancer cell lines and cellular uptake study by MTT assay analysis has been reported as well. Therefore, we proposed that a successful attempt in identifying better alternate drug carrier to deliver curcumin. This investigation shall bring promising nano-formulation for chemotherapy and other biomedical appliances subsequent to a sequence of *in-vivo* screening to mice or other animal models.

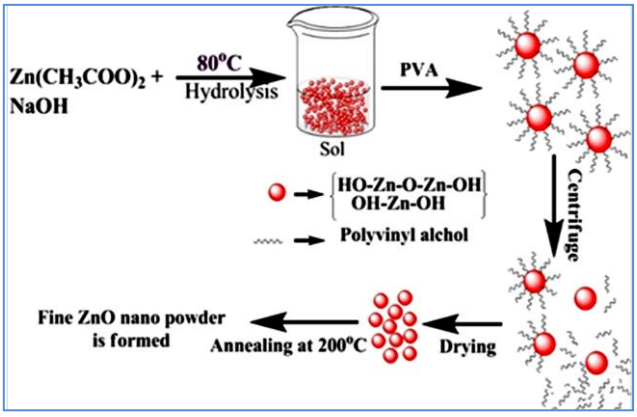
Experimental

Materials

Zinc(II) acetate dihydrate with purity of 99.5% was purchased from Aldrich. Sodium hydroxide (98%) received from Merck. PVA (Molecular weight ≈125,000) was obtained from S.D.fine chemicals, Mumbai, India. Curcumin was purchased from Merck with purity of 97%. All the chemicals used were of analytical grade and used without any further purification. Antibiotic (Amikacin hydrate) was purchased from Sigma Aldrich. AGS human gastric cancer cell line was obtained from NCCS, India. Cells were cultured in 10% complete DMEM-F12 Ham, Fetal Bovine Serum (FBS) and growth media with supplements (Hi media chemicals, India). MTT (3-(4,5-Dimethylthiazol-2-yl)-2,5-diphenyltetrazoliumbromide) reagent was obtained from Calbiochem (Merck Biosciences).

Preparation of ZnO nanoparticles

Zinc(II) acetate (10 g) was treated with NaOH (0.83 g) in appropriate amount of 2-propanal at 80°C under constant stirring for 30 min, it gave a white colored fluffy precipitate. Slow addition of PVA solution as stabilizer to the above reaction mixture and stirring was continued for further 2 hours, this reaction mixture was kept at -14°C for 24 hr. The supernatant was discarded carefully and washed with distilled water by centrifuge technique for at least 10 times to completely remove PVA so as to obtain the desired ZnO nanoparticles as crude solid material. The collected solid material was dried in water bath at 70°C. The powder was annealed at 200°C for 3 hours and ground to get ZnO nanoparticles as fine powder. The following **Scheme 1** reveals the various steps involved in the synthesis.

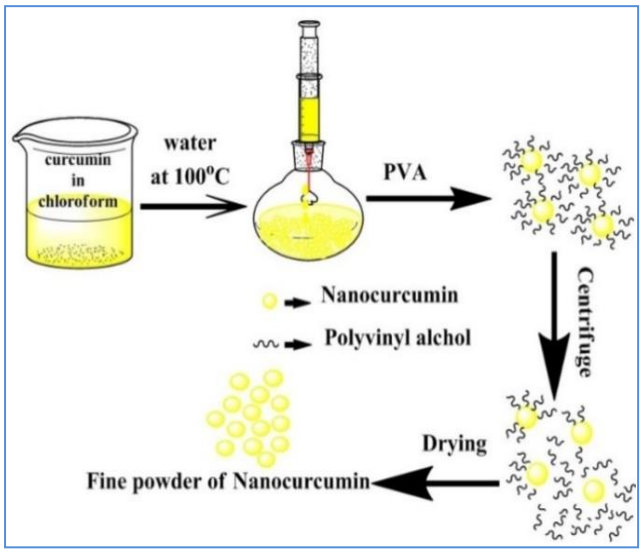


Scheme 1. Graphical representation of the synthesis of ZnO nanoparticles.

Preparation of nanocurcumin

The nanocurcumin has been synthesized as our previous report with slight modification **[17]** and described in the **Scheme 2**. The commercial curcumin dissolved in chloroform was added drop wise in to hot water maintained

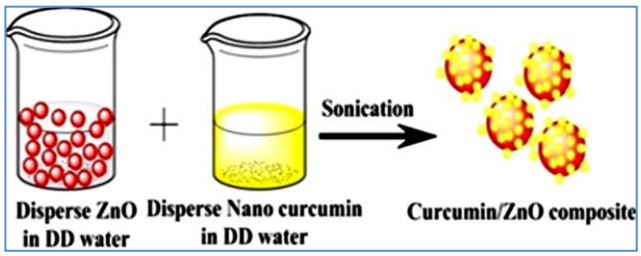
at 70°C and stirred vigorously for one hour. Appropriate amount of PVA in distilled water was added in to the above reaction solution, the temperature was gradually reduced to below 50°C and stirring was continued for another 2 hr. This final solution was kept aside to separate the organic layer for one day at -14°C. The aqueous layer was removed from the reaction solution and it was washed with distilled water for several times to completely remove PVA. The obtained final organic layer which contains curcumin was kept in water bath at 60°C to absolutely evaporate the CH_3Cl, which gave nanocurcumin as fine powder.



Scheme 2. Graphical representation of the synthesis of nanocurcumin.

Preparation of nanocurcumin/ZnO nanocomposite

The new nanocomposite has been synthesized for the first time as follows, the nanocurcumin in ethanol was added drop wisely to the ZnO NPs in DD water under constant sonication and the sonication was continued for another 4 hr. The pale yellow color of the reacting solution turned red indicating the completion of reaction. The obtained reddish orange color solid materials was separated from the solution by repeated centrifuge and dried it to give the fine orange color powder of prolong stable curcumin/ZnO nanocomposite as described in the below **Scheme 3**.



Scheme 3. Graphical representation of synthesis of Curcumin/ZnO nanocomposite.

Growth inhibition in liquid medium

The antibacterial effect of nanocurcumin, ZnO NPs, and curcumin/ZnO nanocomposite were studied in liquid nutrient growth medium on agar plates were studied using the bacteria such as, *E-coli*, *Bacillus subtilis*, *Pseudomonas aeruginosa*, *staphylococcus aureus* culture in nutrient media (1g yeast extract, 1 g beef extract, 0.5 g NaCl, dissolved in 100 ml distilled water). Frozen bacteria cells were grown overnight in the nutrient medium to prepare inoculum. The bacterial cultures were allowed to grow in a shaking incubator at 310 K (37°C) and 200 rpm. ZnO, curcumin nanoparticles and curcumin/ZnO nanocomposite were dispersed in double distilled water by sonication and a desired concentration was made for the whole study. Freshly grown bacterial inoculums (10^4 cells/ml) of bacteria were incubated with ZnO NPs, nanocurcumin and curcumin/ZnO nanocomposite (10 mM) was kept in a flask (50 ml for each bacterial cell) to observe the bacterial cell growth pattern at 310 K (37°C) and 200 rpm.

Determination of antibacterial activity by well diffusion method

Antimicrobial activities of the synthesized ZnO NPs, curcumin/ZnO nanocomposite were performed against both gram-negative (*E. coli and P. aeruginosa*) and gram-positive (*B. subtilis and S. aureus*) strains by well diffusion method. The pure cultures were subcultured in Müller Hinton broth at 35°C±2°C on a rotary shaker at 160 rpm. For bacterial growth, a lawn of culture was prepared by spreading the fresh culture (100 µL) having 10^6 colony-forming units, (CFU)/mL of each test organism on nutrient agar plates with the help of a sterile glass-rod spreader plates, this set-up has been allowed to be kept idle for 10 min to let the culture get absorbed. Then the 8 mm wells were punched into the nutrient agar plates for testing the antibacterial activities of the nanomaterials. Wells were sealed with one drop of molten agar (0.8% agar) to prevent leakage of nanomaterials from the bottom of the wells. 100 µL (0.05mg) of our nanoparticle suspension was added onto each of five wells on all plates using a micropipette. After overnight incubation at 35°C ± 2°C, the observed different levels of zone of inhibition were measured. For these studies, solvent blank was used as negative control and antibiotic Amikacian was used as positive control.

In-vitro drug release kinetics

The *in-vitro* release of curcumin from the synthesized nanocomposite was evaluated using dialysis bag method. 10 mg/ml of nanocomposite was placed in dialysis membrane tube with 12000 Da molecular cut off (Himedia, Dialysis membrane-110). The study of curcumin release was carried out by dipping the tube in a beaker containing 50 ml of PBS buffer. At various time interval, 2 ml of the solution was drawn from the release medium and replaced with fresh PBS buffer. The concentration of the curcumin released from the nanocomposite during the drug releasing process was determined by UV spectrometry (Diode-Array spectrophotometer 8453 value).

Cell culture

The AGS human gastric cancer cell lines were obtained from NCCS, India, cells were cultured in 10% complete DMEM-F12 growth media with supplements (Hi media

chemicals, India). Cell was maintained in a humidified atmosphere at 37°C incubator with 5% of CO_2. Nanoparticles were suspended in culture medium at a concentration of 1 mg/ml and then the solution was sonicated for 15 min. Then the solution was diluted with the medium to different concentration (0.0001 µg, 0.001µg, 0.01µg, 0.05µg, 0.1µg, 0.25 µg, 0.5 µg, 1 µg).

Cell viability assay

In vitro cytotoxicity potentials of the curcumin, ZnO and composite nanoparticles were evaluated in the gastric cancer cell lines (AGS) by MTT assay. The AGS cells were seeded at the concentration of $1x10^4$ cells in 96 well plates and incubated for 48 hours in incubator with 5% of CO_2 at 37°C and the present nanomaterials. The each nanoparticle solutions were diluted in ethanol in 8 different concentrations respectively and 0.1% ethanol served as vehicle control. After 48 hours of treatment with series of concentration, MTT [3-(4, 5-dimethyl-thiazol-2-yl)], 2-5-dipheyl tetrazolium bromide was added to each well at 0.5 mg/ml concentration. After incubation for 4 hours in CO_2 incubator, media was carefully removed and the purple formazan precipitate was dissolved in 100 ml/well DMSO and kept incubator for 15 min in dark. Estimation of formazan product was performed at 570 to 690nm in a microplate reader. The assay was performed in triplicates. The data was plotted against the drug concentration and the relative cell viability (%) in comparison to the control cells with vehicle treatment.

Physical measurements

The structure and morphology of the resulting particles were characterized by XRD Bruker X-ray diffractometer (Model AXS D8 Advance using Cu Wavelength 1.5406 Å). The UV-Vis absorption spectra were obtained with Diode-Array spectrophotometer 8453 value UV-Visible system. Transmission electron microscopic images were performed with a TF 20: Tecnai G2 200kV TEM (FEI). The sample for TEM was prepared by placing a drop of sample suspension in ethanol onto a carbon coated copper grid. Cell imaging was carried out in perkinelmex (USA).

Results and discussion

XRD pattern of ZnO and curcumin/ZnO nanocomposite

The X-ray diffraction pattern of ZnO nanocrystalline powder has shown in the **Fig. 1(a)**. A definite line broadening of the XRD peaks indicates that the prepared material consist of particles are in the nanoscale range. The diffraction peaks observed at 2θ values are 31.73°, 34.38°, 36.21°, 47.50°, 56.56°, 62.82°, 66.34°, 69.04° and 72.54°, from the calculated lattice constants a = b = 3254 Å and c = 5202 Å, this observed pattern declares that these ZnO nanoparticles are as hexagonal wurtzite phase (JPCDS card number: 36-1451) **[22]**. The absence of any additional peaks declares that these are free from impurities. The d-spacing value calculated from XRD is 0.2477 nm **[23]**.Their diameter was calculated using Debye-Scherrer formula, the average particle size of the sample was found to be 21.44 nm.

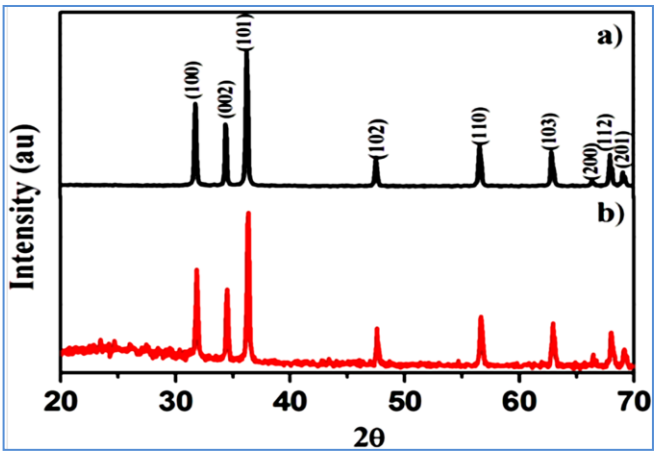


Fig. 1. XRD pattern of the synthesized ZnO and curcumin/ZnO nanocomposite.

The X-ray diffraction pattern for curcumin/ZnO nanocomposite (**Fig. 1(b)**) clearly revealed that the peak positions exactly similar to the ZnO NPs, there by concluding that the newly coated curcumin did not disturb the crystal lattice of ZnO nanoparticles. The d-spacing for the title composite is 0.259 nm. The average particle size of nano composite was found to be 24.66 nm. The calculated lattice constants a = b = 3245 Å and c = 3621 Å and the observed pattern also declare that nanocomposite has hexagonal wurtzite phase (JPCDS card number: 36-1451) as similar as ZnO nanoparticles. Its amorphous nature in the baseline may be due to the attached nanocurcumin on the surface of ZnO nanoparticles through its active site.

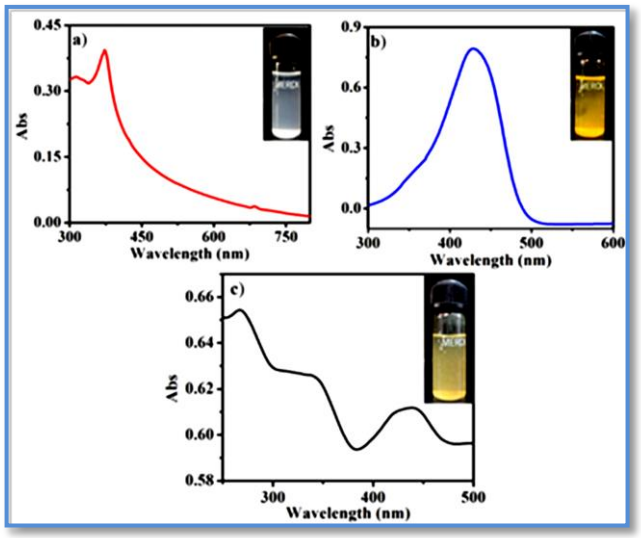


Fig. 2. UV-Visible spectra and the color differences of a) ZnO b) curcumin c) curcumin/ZnO nanocomposite.

Electronic spectra

The absorption spectra of ZnO nanoparticles, nanocurcumin and curcumin/ZnO nanocomposite are illustrated in **Fig. 2**. ZnO NPs and nanocurcumin exhibit

their characteristic strong absorption bands at 372 **[24]** and 425 nm **[25]** respectively. The electronic spectra of curcumin/ZnO nanocomposite showed two bands at 352 and 440 nm.

It is observed that these two bands at 352 and 440 nm for nanocomposite material experienced blue shift from the band responsible for ZnO NPs (372 nm) and red shift from curcumin absorption band (425nm) respectively, which confirms the formation of strong layer of nanocurcumin on the surface of ZnO NPs which is also justified by the decrease in ZnO nanoparticle size after sonication.

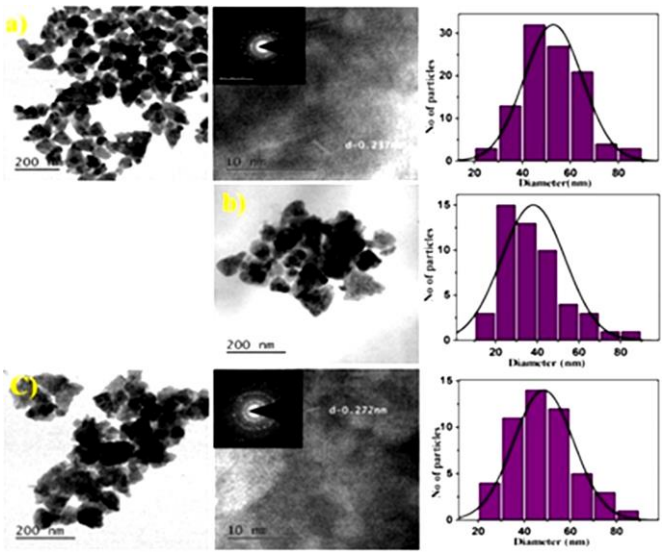


Fig. 3. TEM images of (a) ZnO nanoparticles (b) nanocurcumin and (c) curcumin/ZnO nanocomposite.

Surface morphology

Transmission electron microscopy

Representative TEM images and histogram of the particle size distribution of ZnO Nps, nanocurcumin and nanocomposite are shown in **Fig. 3**. The average particle size obtained from TEM images are 48, 38 and 53 nm respectively for ZnO NPs, nanocurcumin and nanocomposite materials respectively. TEM micrograph of the ZnO NPs shows well-defined nano scaling and remarkably single dispersed particles which also appear to be in uniform size and shape. TEM images of nanocurcumin (**Fig. 3(b)**) and nanocomposite materials (**Fig 3(c))** indicate that the particles lie in nanoscale region.

The observed image for the composite material clearly indicates that the nanocurcumin was incorporated with surface of the ZnO nanoparticles which lead to a little agglomeration of the particles, thus the mean particle size increases up-to 53 nm. The ZnO nanoparticles were not altered significantly which denotes that the incorporated nanocurcumin completely surrounds only on the surface and never destroy the chemical or structural composition of ZnO. The d-spacing values determined by TEM images are nearly close to the d-spacing values of calculated from XRD results.

pH dependent nanocurcumin release

The curcumin releasing behavior from the novel nanocomposite material has been investigated using phosphate buffer and DMSO mixture solution (1:1 ratio) for 15 hours in two different pH values (7.4 and 5.8) at 37°C. The pH responsive curcumin release is illustrated in the **Fig. 4(a** and **b).** The observed results showed that the drug releasing rate decreased with the increasing pH values. Curcumin release was slow and sustained at pH 7.4 with release rate of 56 ± 0.27%, whereas at pH 5.8 curcumin release rate found to be 89 ± 0.62%. These experiments have been repeated for several times in order to get concordant values. The obtained rate of curcumin release is much faster in acidic medium (pH 5.8) than at pH 7.4 at the given time (15 h). The pH of the tumors was 5.0–6.0, which is lower than the pH of normal tissues, so curcumin releases from the new nanocomposite material could be at the tumor site. Therefore, the presently observed results are substantiated the pH dependent drug release behavior of the drug delivery system.

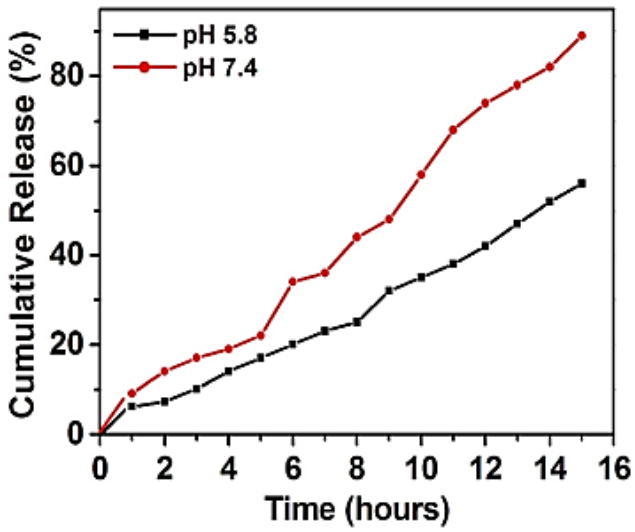


Fig. 4. pH-dependent *in vitro* curcumin release profiles from ZnO nanocomposite at (a) acidic pH, 5.8 and (b) neutral pH, 7.4.

Antibacterial properties

ZnO NPs are the most effective inorganic materials to inhibit certain food borne pathogens in the food system and they possess strong antibacterial activities. They are more toxic towards both halophilic and mesophilic bacteria. In this present work, we have investigated the activity of title nanomaterials against mesophlic bacteria. The nanotoxicity is more pronounced on Gram negative and significantly less toxic towards Gram positive cells. Among the various metal oxides studied for their antibacterial activity, ZnO nanoparticles have been found to be highly toxic. Moreover, their stability under harsh processing conditions and relatively low toxicity combined with the potent antimicrobial properties favors their applications as antimicrobials **[7]**. Therefore we anticipate that the antibacterial activity of ZnO NPs can be enhanced by making a composite with the well-known phyto compound curcumin, since it has much efficient and wide range of medicinal applications in biomatters **[26]**. So we made an attempt to investigate the activity efficiency of

nanocurcumin and ZnO NPs comparatively with the curcumin/ZnO nanocomposite towards the bacteria (**Fig. 5**). The observed results are indicated that the activity against *Staphylococcus aureus, bacillus subtilis* (both gram-positive), *E-Coli, Pseudomonas aeruginosa* (both gram-negative) by the nanocomposite was much efficient than the bare ZnO NPs and nanocurcumin. This observation may be due to the presence of curcumin along with ZnO NPs, which made the material more biocompatible and more toxic towards the bacteria in water and ethanol as a solvent system was illustrated in the **Fig. 6**.

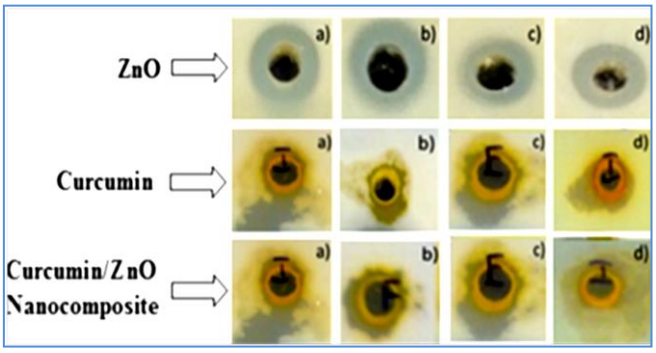


Fig. 5. Zone of inhibition produced by ZnO nanoparticles, nanocurcumin, and curcumin/ZnO nanocomposite against both gram-positive and gram-negative bacterial strains, (a) *Escherichia coli*, (b) *Staphylococcus aureus*, (c) *Pseudomonas aeruginosa*, and (d) *Bacillus subtilis.*

The presence of nanoparticles at a certain level inhibited bacterial growth by more than 90 %, this reveals that the present nanomaterials acts as excellent antibacterial agents against both gram negative and gram positive bacteria. The order of antibacterial activity of nanomaterials is nanocomposite > ZnO NPs > nanocurcumin. As expected nanocurcumin showed very efficient activity against the bacterial strains than its original commercial counter parts which is due to its enhanced aqueous solubility (900 times greater solubility than commercial curcumin, **S. Fig. 1**) consequently improved potential bioavailability. The size of the nanoparticles might also play significant role in the antibacterial activity. However, it should also be noticed the nanocomposite material is the most toxic nanomaterial for most of the human pathogens as our anticipation among the two other nanomaterials in both water and ethanol as solvents.

Curcumin/ZnO nanocomposite exhibited maximum (17 mm) bacterial growth inhibition against Gram negative bacteria in the form of zone-of-inhibition studies. In this study, nanocomposite showed 86% of activity in water and 96% of activity in ethanol respectively towards the different bacterial strains which are involved in this study. The activity of nanocomposite is more effective than the bare ZnO NPs (82% of zone of inhibition for gram negative strains of *E-Coli and P.aeruginosa*) in ethanol. In the case of nanocurcumin in water shows 76% of zone-of-inhibition, which is also higher than gram positive bacterial strains in water. In the case of ethanol medium ZnO nanoparticle, nanocurcumin and nanocomposite showed higher sensitivity declare that the nanotoxicity of the present nanomaterials is pronounced for the gram negative bacteria than the positive as expected. The enhanced activity is attained for these nanomaterials due to the strong attack of curcumin/ZnO nanocomposite on the surface of the cell wall and slowly penetrated into the inside cell consequently kill the bacteria. Since the title nanocomposite has smaller particles size (53 nm) thus made it easy to penetrate the cell wall.

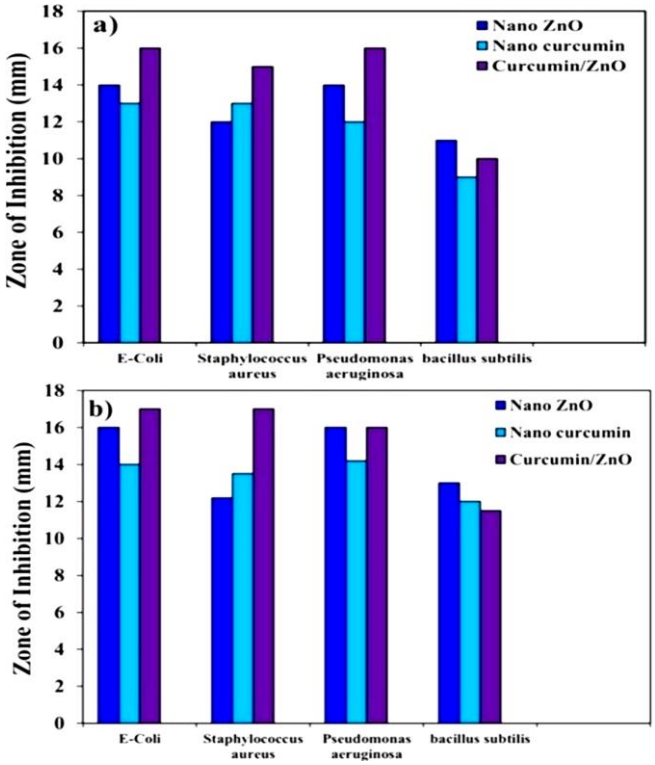


Fig. 6. Bar graphs showing zone of inhibition introduced by nanocurcumin, ZnO nanoparticles and curcumin/ZnO nano composite against various microorganisms in (a) water and (b) ethanol.

In-vitro cytotoxicity analysis of nanomaterials on AGS gastric cancer cell lines

The anticancer activity of curcumin has been studied worldwide by many researchers. Our previous report also described that the enhanced solubility as well as anticancer properties of highly soluble PVA loaded nanocurcumin compared to its original counterparts **[15]**. In the present work we are interested to assess the enhanced anticancer activity of ZnO nanoparticles, and curcumin/ZnO nanocomposite along with nanocurcumin as similar as antibacterial activity. As our anticipation the curcumin/ZnO nanocomposite shows greater activity against cancer cells, since, we conjugate two biologically important materials such as ZnO along with curcumin. When, two or more bioactive materials combine together, eventually its bioavailability also might be superior. So we like to construct this new nanocomposite using nanocurcumin with ZnO NPs and investigate its efficient bioactivity against bacteria and cancer cells. Therefore, obviously it shows better anticancer properties against gastric cancer cells as similar as its efficient anti-bacterial properties against gram negative bacteria as our above

discussion. The other nanomaterials also have been evaluated for their anticancer activities using the MTT assay.

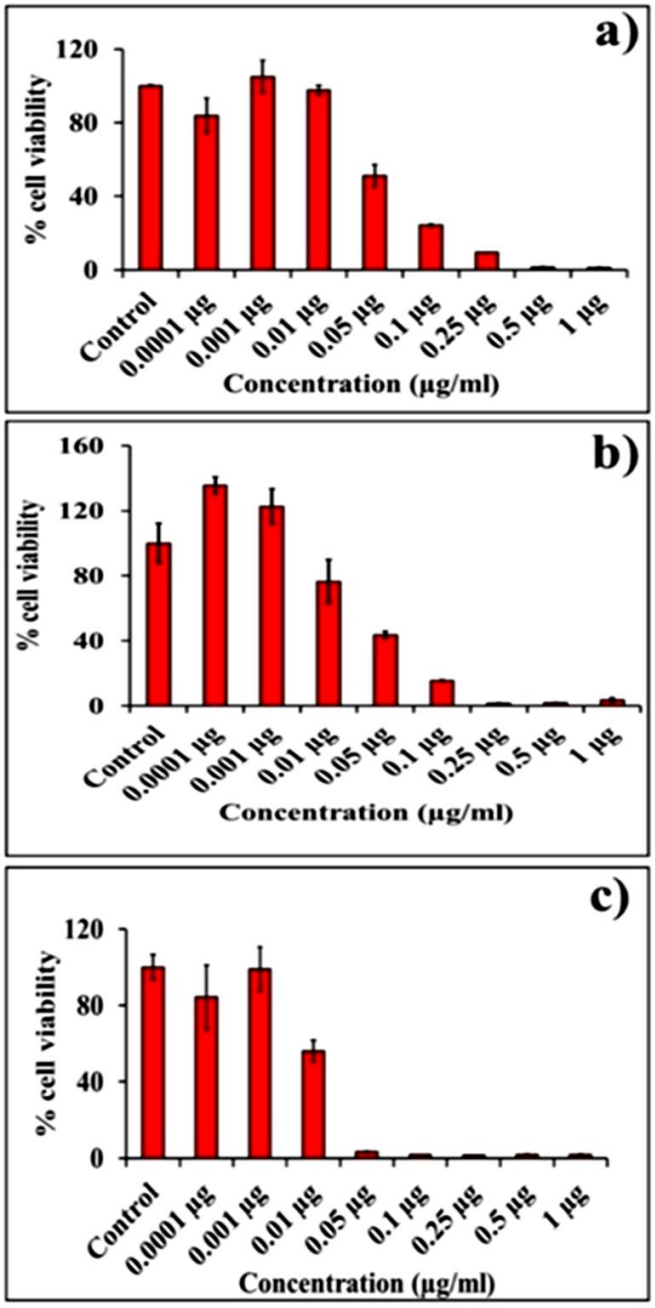


Fig. 7. Cytotoxicity assay of AGS gastric cancer cell lines treated with composite nanoparticles.

These assessments have been carried out after the exposure of AGS cancer cell lines with the title nanomaterials for 24 and 48 hours respectively. It is obvious that the anticancer activity of nanocurcumin has been much efficient than its original commercial counter part due to its enhanced solubility in water and other organic solvents. The AGS cells exposed to nanocomposite has 50% viable cells at concentration of 0.01 µg/ml, the decreased cell viability in a dose dependent manner has been illustrated from the **Fig. 7(c)**. The cell viability was observed to be 50% for cells treated with ZnO nanoparticles and nanocurcumin at 0.05 µg/ml respectively as shown in **Fig. 7 (a** and **b)**. These results clearly illustrates that this novel nanocomposite shows potent cytotoxicity against AGS cell lines compared to other nanoparticles even at low concentration and serving as an efficient drug carrier. The mechanism of anticancer against AGS cancer cells was investigated based on IC_{50} values of the title nanomaterials. The untreated AGS cells show no apoptosis, whereas the cancer cells which are treated with the present nanoparticles showed characteristic feature of apoptosis by changing their morphologies as illustrated in the **Fig. 8.** Moreover, these observations declare that the nanocomposite could serve as an effective drug carrier against gastric cancer cells. It may be commercialized due to its potent bioactivity after a series of in-vivo tests with animal models.

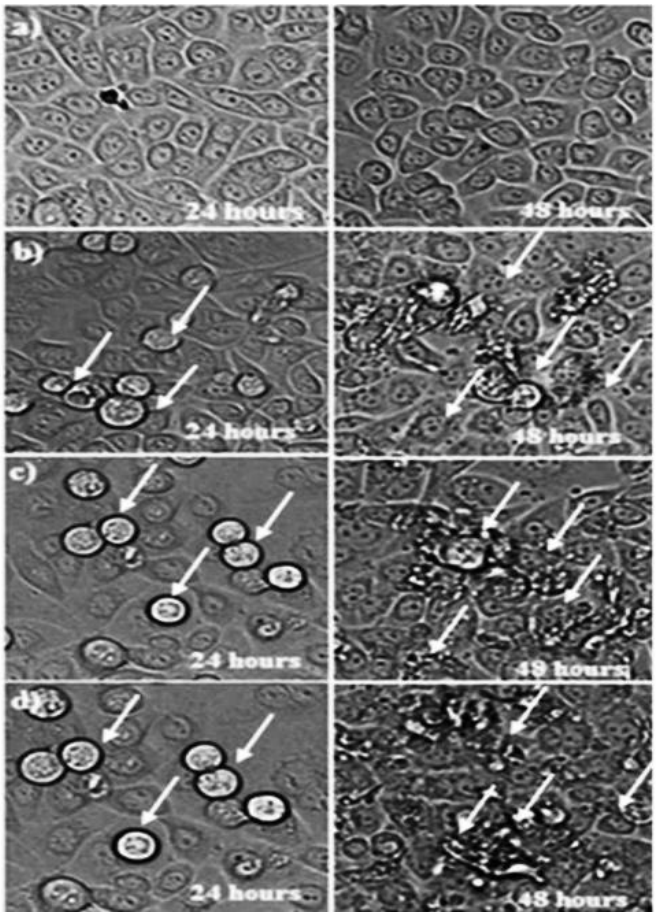


Fig. 8. Bright field image of AGS cancer cells treated with (a) control (b) ZnO nanoparticles (c) nanocurcumin and (d) nanocomposite.

Conclusion

A new curcumin/ZnO nanocomposite has been successfully prepared and completely characterized. The morphology of this nanomaterial also has been evaluated using TEM. The major advantage of this nanocomposite may be due to its enhanced aqueous solubility. They showed a greater anti-bacterial activity it has potential toxicity towards gastric cancer cells. They may commercialize for chemotherapy and other biomedical appliances after a sequence of *in-vivo* screening, it is under progress in our lab.

Acknowledgements

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