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DESIGN AND DEVELOPMENT OF CURCUMIN LOADED NANOPARTICLES FOR ANTIBACTERIAL ACTIVITY

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ABSTRACT

Nanoparticles are of great scientific interest as they are effectively a bridge between bulk materials and atomic or molecular structures.(4) Presently, numerous of methods have been reported for the synthesis of nanoparticles. Size reduction of targeted formulation and designing its pathways for suitable drug delivery system is a more fundamental and successful approach that forms the basis of nanotechnology. Recent advancement in nanotechnology has proven that nanoparticles acquire a great potential as drug carriers. Size reduction methods and technologies yields different types of nanostructures that exhibit unique physicochemical and biological properties. **MATERIALS:** Curcumin (Loba chemie Pvt. Ltd., Mumbai), Methanol (Loba chemie Pvt. Ltd., Mumbai), Ethanol (Loba chemie Pvt. Ltd., Mumbai), Gelatin (Loba chemie Pvt. Ltd., Mumbai,) The main aim of the research work was to develop a nanoparticles. On characterization spherical nanoparticles with smooth surface were observed under transmission electron microscopy (TEM). Zeta potential of NPs provides satisfactory evidence about their little tendency towards aggregation when its negative charge confirms the presence of strong electric charges on the particle surfaces to hinder agglomeration. The X-ray diffraction pattern of the synthesized nanoparticles showed diffraction peaks at 2θ, which are compared with standard powder diffraction peaks. The experiments on particle size characterization confirmed that the synthesis of nanoparticles in the growth media was successful and had also provided us with estimates about the particle size and morphology. **CONCLUSION:** According to antibiotics screening results zone of inhibition formulation showed more activity for *S. aureus and P Aerugonisa.* NPs formulation of Curcumin alters the chemical structure of Curcumin and it becomes active against resistant bacteria.

KEYWORDS: Nanoparticles, Curcumin, Antibacterial activity.

INTRODUCTION

Nanotechnology is rapidly growing by producing nano products and nanoparticles (NPs) that have novel and size-related physico-chemical properties. Recent advancement in nanotechnology has proven that nanoparticles acquire a great potential as drug carriers. These methods make the nanostructures favorable material for biomedical applications and thus acquire the significance importance in pharmaceutical sciences. In addition these methods help in reducing toxicity, enhancing release, improving solubility and bioavailability and provide better formulation opportunities for drugs. (1)

Advantages of nanoparticles as a drug delivery system

- Particle size and surface characteristics of nanoparticles can be easily manipulated to achieve both passive and active drug targeting after parenteral administration.
- They control and sustain release of the drug during the transportation and at the site of localization, altering organ distribution of the drug and subsequent clearance of the drug so as to achieve increase in drug therapeutic efficacy and reduction in side effects.
- Controlled release and particle degradation characteristics can be readily modulated by the choice of matrix constituents. Drug loading is relatively high and drugs can be incorporated into the systems without any chemical reaction; this is an important factor for preserving the drug activity.
- Site-specific targeting can be achieved by attaching targeting ligands to surface of particles or use of magnetic guidance.
- The system can be used for various routes of administration including oral, nasal,parenteral, intra-ocular etc.
- Nanoparticles have property of altering the properties and structures of drugs.

Disadvantages of nanoparticles

- Their small size and large surface area can lead to particle particle aggregation, making physical handling of nanoparticles difficult in liquid and dry forms.
- Large surface can make them too reactive in some situations.
- Changes properties of a material.
- Might be toxic to some type of cells such as skin, bone, brain and liver cells.(2,3)

Classification of Nanoparticles

The nanoparticles are generally classified into the organic, inorganic and carbon based.

Organic nanoparticles

Dendrimers, micelles, liposomes and ferritin, etc. are commonly knows the organic nanoparticles or polymers. These nanoparticles are biodegradable, non-toxic, and some particles such as micelles and liposomes has a hollow core (Figure1.1), also known as nanocapsules and are sensitive to thermal and electromagnetic radiation such as heat and light. These unique characteristics make them an ideal choice for drug delivery. The drug carrying capacity, its stability and delivery systems, either entrapped drug or adsorbed drug system determines their field of applications and their efficiency apart from their normal characteristics such as the size, composition, surface morphology etc. The organic nanoparticles are most widely used in the biomedical field for example drug delivery system as they are efficient and also can be injected on specific parts of the body that is also known as targeted drug delivery.

Inorganic nanoparticles

Inorganic nanoparticles are particles that are not made up of carbon. Metal and metal oxide based

nanoparticles are generally categorized as inorganic nanoparticles.

Metal based

Nanoparticles that are synthesized from metals to nanometric sizes either by destructive or constructive methods are metal based nanoparticles. Almost all the metals can be synthesized into their nanoparticles. The commonly used metals for nanoparticles synthesis are aluminum (Al), cadmium (Cd), cobalt (Co), copper (Cu), gold (Au), iron (Fe), lead (Pb), silver (Ag) and zinc (Zn). The nanoparticles have distinctive properties such sizes as low as 10 to 100nm, surface characteristics like high surface area to volume ratio, pore size, surface charge and surface charge density, crystalline and amorphous structures, shapes like spherical and cylindrical and color, reactivity and sensitivity to environmental factors such as air, moisture, heat and sunlight etc. (5,6)

CURCUMIN

Curcumin is one such medicine. Turmeric derived from the rhizome of the plant Curcuma longa has been used by the people of the Indian subcontinent for centuries with no known side effects, not only as a component of food but also to treat a wide variety of ailments. Curcumin, a polyphenol, is an active principle of the perennial herb Curcuma longa. The yellow color of turmeric is mainly due to the presence of polyphenolic curcuminoids, which constitute approximately 3% to 5% of most turmeric preparations. The turmeric mainly contains three curcuminoids, namely curcumin, desmethoxycurcumin, and bisdesmethoxycurcumin.

Traditional uses of curcumin

Traditionally, turmeric has been put to use as a foodstuff, cosmetic, and medicine. As a spice, it is used to provide curry with its distinctive yellow color and flavor. It is used as a coloring agent in cheese, butter, and other foods. In folk medicine, turmeric and natural curcuminoids have been applied as therapeutic preparations over the centuries in different parts of the world. In Ayurvedic medicine, curcumin is a well-documented treatment for various respiratory conditions (e.g., asthma, bronchial hyperactivity, and allergy) as well as for liver disorders, anorexia, rheumatism, diabetic wounds, runny nose, cough, and sinusitis. In traditional Chinese medicine, it is used to treat diseases associated with abdominal pain. In ancient Hindu medicine, it was used to treat

sprains and swelling .Throughout the Orient, it has traditionally been used to good therapeutic effect, particularly as an anti- inflammatory, and many of its therapeutic effects have been confirmed by modern scientific research. Such effects include antioxidant, anti-inflammatory, anticarcinogenic and antimicrobial, hepatoprotective, thrombosuppressive cardiovascular (i.e., as protection against myocardial infarction) , hypoglycemic, and antiarthritic (i.e., as protection against rheumatoid arthritis), The most compelling and key rationale for the continuing traditional therapeutic use of curcumin is its extremely good safety profile.(9,10)

Curcumin Nanoparticles

Curcumin in the form of nanoparticles is a widely reported form for enhancing the bioavailability and solubility of lipophilic curcumin. Curcumin nanoparticles can be more bioavailable and deposited more highly than the normal curcumin in comparison of the tissues of the Sprague-Dawley rat model. However, no form of curcumin or its closely related analogues poses the properties required for a good drug or additive candidate in terms of chemical stability, high water solubility, potent and selective target activity, high bioavailability, broad tissue distribution, stable metabolism and low toxicity.

MATERIALS:

Curcumin	LOBA CHEMIE Pvt. Ltd., Mumbai, India.
Methanol	LOBA CHEMIE Pvt. Ltd., Mumbai, India.
Ethanol	LOBA CHEMIE Pvt. Ltd., Mumbai, India.
DMSO	Nice chemicals Pvt. Ltd., Mumbai, India.
Gluteraldehyde	LOBA CHEMIE Pvt. Ltd., Mumbai, India.
Gelatin	LOBA CHEMIE Pvt. Ltd., Mumbai, India.
Acetone	LOBA CHEMIE Pvt. Ltd., Mumbai, India.
Disodium hydrogen phosphate	S.D. Fine Chem. Ltd., Mumbai, India.
Potassium Dihydrogen orthophosphate	LOBA CHEMIE Pvt. Ltd., Mumbai, India.
Hydrochloric acid	RANKEM laboratory reagent, NEW DELHI.

Method of synthesis of nanoparticles

Accurately weighed 2.5 gm of gelatin and add 50 ml of water and dissolve. After this add 50 ml of acetone mix well and sediment the solution for 2 hours. After 2 hour, supernatant liquid is discarded. The sediment liquid re-dissolves in 25 ml of water. Maintain the pH by adding Hal.

After this, add acetone drop by drop through burette. After turbidity appear, add 5 ml of Gluteraldehyde and mix the solution for 2 hrs. Finally, lyophilizes the solution and nanoparticles was collected.2 g of Curcumin was dissolved in methanol and added to nanoparticles. [71]

Preformulation studies

Preformulation study is the first step in the rational development of dosage forms of a drug substance. It can be defined as an investigation of physical and chemical properties of a drug substance alone and when combined with excipients. The overall objective of preformulation testing is to generate information useful to the formulator in developing stable and bioavailable dosage forms. Following preformulation studies were performed.

Organoleptic properties

The organoleptic studies like general appearance like nature, color, odor, etc. were performed by visual observations and compared with standard of drug given in pharmacopoeia for identification of drug.

Color: Small quantity of drug was taken on butter paper and viewed in well illuminated place.

Odor: Very less quantity of drug was smelled to get the odor.

Solubility studies

Semi quantitative determination of the solubility was made by adding solvent to glass tube containing accurately weighed amount of solute. The system is vigorously shaken and examined visually for any undissolved solute particles. The solubility is expressed in terms of ratio of solute and solvent. The solubility study of Curcumin was performed in distilled water, ethanol, methanol, phosphate buffer solution pH 7.4 and DMSO, separately by keeping the drug containing test tube on vortex mixture.

Determination of melting point

For determination of melting point USP method was followed. Small quantity of drug was placed into a sealed capillary tube. The tube was placed in the melting point apparatus. The temperature in the apparatus was gradually increased and the observation of temperature was noted at which drug started to melt and the temperature when the entire drug gets melted was noted.

Differential scanning calorimetry (DSC)

All dynamic DSC studies of pure drug were carried out on DSC TA 60 Shimadzu thermal analyzer. The instrument was calibrated using high purity indium metal as standard. The scans were taken in nitrogen atmosphere at the heating rate of 10°C/min.

Determination of drug pH

The pH of Curcumin was determined using digital pH meter for freshly prepared 1% solution of Curcumin in methanol.

Infrared spectroscopic analysis

The fourier infrared spectrums of moisture free samples of Curcumin, excipients and physical mixture were recorded on IR spectrophotometer. Infrared spectroscopy of different compounds was performed for identification of that particular compound. Various peaks in FTIR spectrum were interpreted for identification of different group in the structure of Curcumin. FTIR Spectroscopy can also be used to investigate and predict any physicochemical interactions between different components. The scanning range varies from 4000 – 400 cm^{-1} and the resolution was 1 cm^{-1}.

Analysis by UV-Visible spectrophotometry

Determination of wavelength maxima of Curcumin

Preparation of standard curve in methanolStandard stock solution of Curcumin

Accurately weighed 100 mg of Curcumin and was dissolved in 100 ml of methanol, from this stock solution 10 ml was withdrawn and transferred into 100 ml volumetric flask. Volume was made with methanol in order to get standard stock solution containing 100 μg/ml.

Standard graph of Curcumin: Form this standard stock solution, a series of dilution (2, 4, 6, 8, 10 μg/mL) were prepared using methanol. The absorbance of these solutions was measured spectrophotometrically against blank of methanol at 425 nm for Curcumin. [70]

Evaluation of nanoparticles

Drug entrapment efficiency

The total volume of the nanoparticles suspension was measured. 5ml of this formulation was diluted with distilled water up to 8 ml and centrifuged at 15,000 rpm for 45 min at 4^0C using a cooling centrifuge. After centrifugation, the supernatant and sediment were recovered, their volume was measured. Then sediment was lyses using n-propanol and filtered through a 0.45 µm nylon disk filter.[72] The concentration of curcumin in the supernatant and sediment was analyzed by UV- spectroscopic method at 425 nm. The percent drug entrapment was calculated using the following equation:

$$\% \text{ Entrapment efficiency: } \frac{\text{Amount of entrapped drug recovered}}{\text{Total amount of drug}} \times 100$$

Nanoparticle shape and surface morphology: Preparing sample for TEM is very complex. Less than 100 nanometers specimens for TEM should be mandatory . Like neutrons or radiations of Xrays. The electron present in beams counteract basically with the sample likewise neutron or X- Ray radiations are present in the beam. An effect with was seen with High quality samples having high quality definately have a thickning that if we compare to electrons mean free path that may pass via the test substance, which should be in nanometers. Specimens for preparation of TEM are only special materials for under testing analysis.

Nanoparticles were visualized using transmission electron microscopy (TEM Philips Technai electron microscope, Netherlands). A drop of nanoparticles solution was dried on a microscopic carbon coated grid, to get adsorbed and the surplus was removed by filter paper. A drop of 1% aqueous solution of phosphotungstic acid (PTA) was then added and left in contact with the sample for 5 minutes.[73] The excess solution was removed and the sample was dried at room condition before the vesicles were viewed under TEM operating at an acceleration voltage of 200KV.

Particle size measurement

The size of nanoparticles was determined by dynamic light scattering method (DLS), using a computerized inspection system (Malvern Zetasizer Nano-ZS, Malvern, U.K.) with DTS (Nano) software. For size measurement, nanoparticles solution was diluted with distilled water and put into the cuvettes of zetasizer. Then the measurements were conducted at 25^0C. The DLS measurement were performed over alternating increasing and decreasing temperature cycles at each temperature the sample was equilibrated for at least 3 minutes before performing the measurement. The average hydrodynamic diameter of the nanoparticles under consideration.

Zeta potential measurement

Zeta potential is a physical property which is given the net surface charge of the nanoparticles, when these particles inside the solution repelling each other's since produced Coulomb explosion between the charges of the nanoparticles giving rise to no tendency for the particles to agglomerate. The criteria of stability of NPs are measured when the values of zeta potential ranged from higher than +30 mV to lower than -30 mV. Surface zeta potentials were measured using the laser zeta meter (Malvern zeta seizer 2000, Malvern). Liquid samples of the nanoparticles (5ml) were diluted with double distilled water (50 mL) using NaCl as suspending electrolyte solution (2 x10-2 M NaCl). The pH was then adjusted to the required value. The samples were shaken for 30 minutes. After shaking, the equilibrium pH was recorded and the zeta potential of the metallic

particles was measured. A zeta potential was used to determine the surface potential of the nanoparticles. In each case, an average of three separate measurements was reported. The criteria of stability of NPs are measured when the values of zeta potential ranged from higher than +30 mV to lower than -30 mV.

X-ray diffraction

Scattering of X-rays by atoms of a crystal produces interference so that diffraction pattern gives information on the structure of the crystal or identity of a crystalline substance. 1 ml of the copper nanoparticles solution was spread on a glass slide and dried at 40ºC in an oven. The process was repeated 3-4 times to obtain a thin film. The spectra were recorded in a Phillips Xpert Pro Diffractometer (Cu Kα radiation, λ = 1.54Å) running at 40 kV and 30 mA. The diffracted intensities were recorded from 10 degrees to 80 degrees 2θ angles.[76]

Antimicrobial activity studies

Antimicrobial activity has been assayed against two different of bacteria (one gram-positive and one gram-negative) by agar diffusion method. Generally, the antibiotics activity of a compound is expressed in terms of its ability to inhibit the growth of bacteria in nutrient broth or agar. The bacterial inhibition can be measured by Cup-plate method. In this method, cups or discs of Standard diameter are made in the nutrient agar medium, containing standard bacterial inoculums. The test compounds are introduced into the disc and the diameter of the zone of inhibition was measured. All the test compounds were evaluated for antibiotics activity against *Staphylococcus aureus* (gram-positive) *and Pseudomonas Aeruginosa.*

Here the drug is allowed to diffuse through a solid medium so that a gradient is established, the concentration being highest near the site of application of the drug and decreasing with distance. The test bacterium is seeded on the medium and its sensitivity to the drug determined from the inhibition of its growth. Several methods have been used for the application of the drug. It may be added to ditches or holes cut in the medium or to hollow cylinders placed on it. Ditches or hole is 6 mm in diameter and charged with appropriate concentrations of the drugs. The discs are stored dry in the cold. A suitable dilution of a broth culture or a broth suspension of the test bacterium is flooded on the surface of a solid medium (Mueller—Hinton agar or nutrient agar). The plate is tilted to ensure uniform spreading and the excess broth pipette off. Inoculation may also be performed by spreading with swabs. After drying the plate (37 °C for 30 min.), discs (four or five per 10 cm plate) are applied with sterile forceps. After overnight incubation, tile degree of sensitivity is determined by measuring the zones of inhibition of growth around the disc.

RESULTS AND DISCUSSION

Organoleptic properties

The following properties of drug were evaluated and results are obtained as:

Table 5.1: Organoleptic properties of Curcumin

Test	Specification	Observation
Colour	Yellowish	Yellow

Odour	Pungent Odour	Pungent odour
Appearance	Fine powder	Fine powder

The observations noted were compared to the specifications confirm the identity of the drug and it was found that observation noted complied with specifications.

Solubility analysis

Solubility studies are performed to determine the solubility of drug in different solvents. The solubility is expressed in terms of ratio of solute and solvent**.** Curcumin was found to be soluble in methanol, acetone, ethanol, distilled water, PBS of pH 5.5,6.8, 7.4 and chloroform.

Table 5.2: Solubility profile of Curcumin

Solvent	Inference
Methanol	Soluble
Chloroform	Freely soluble
Ethanol	Sparingly soluble
DMSO	Readily soluble
Distilled water	Slightly soluble
PBS pH 6.8	Slightly soluble
PBS pH 7.4	Slightly soluble

Melting point determination

Melting point of Curcumin was found to be 180 ^{0}C. Melting point was measured three times and mean was noted. A sharp transition took place from solid to liquid at 180^{0}C, indicating that the sample was pure and free from impurities.

Differential scanning calorimetry

The DSC thermograms showed sharp endothermic peak corresponding to Curcumin melting point 180°C for Curcumin. The DSC thermograms of Curcumin is

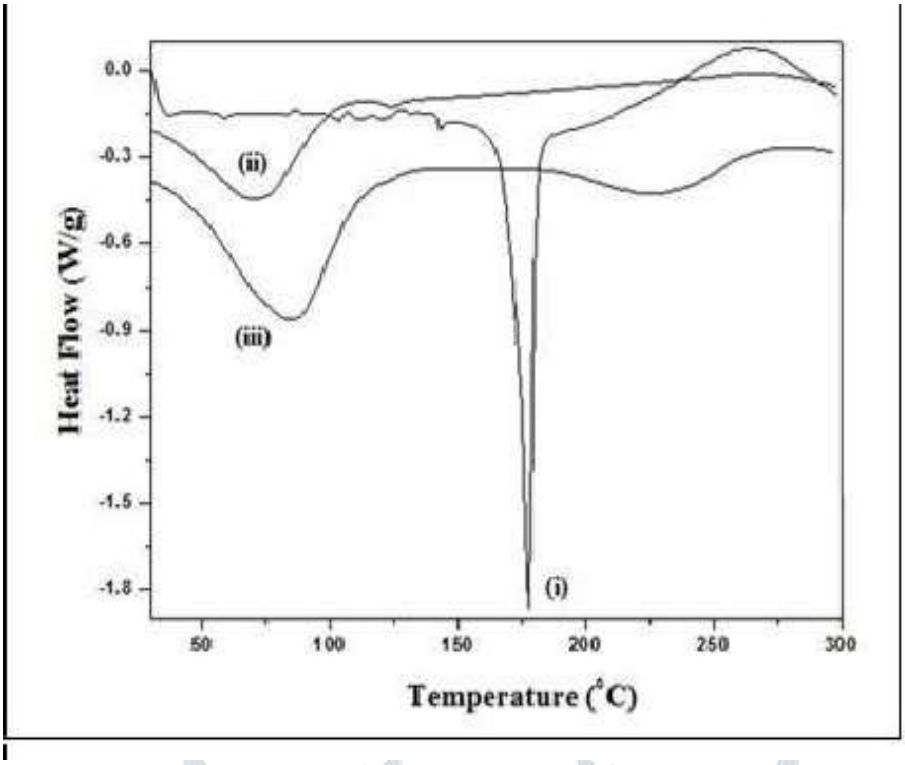

Figure 5.1 DSC thermograms of Curcumin.

Determination of pH of drug

The pH was measured three times and mean was noted. Hence pH of Curcumin was found to be 5.4.

FTIR analysis:

FTIR spectroscopic analysis was carried out to characterize drug. The FTIR spectra obtained was compared with the Curcumin. Diagnostic peaks and finger print regions were found identical. These characteristics peaks are useful in identification of drug.

FTIR of Curcumin and mixture containing Curcumin was done for drug compatibility studies. The results obtained showed that there occur no interactions between the components whentaken together.

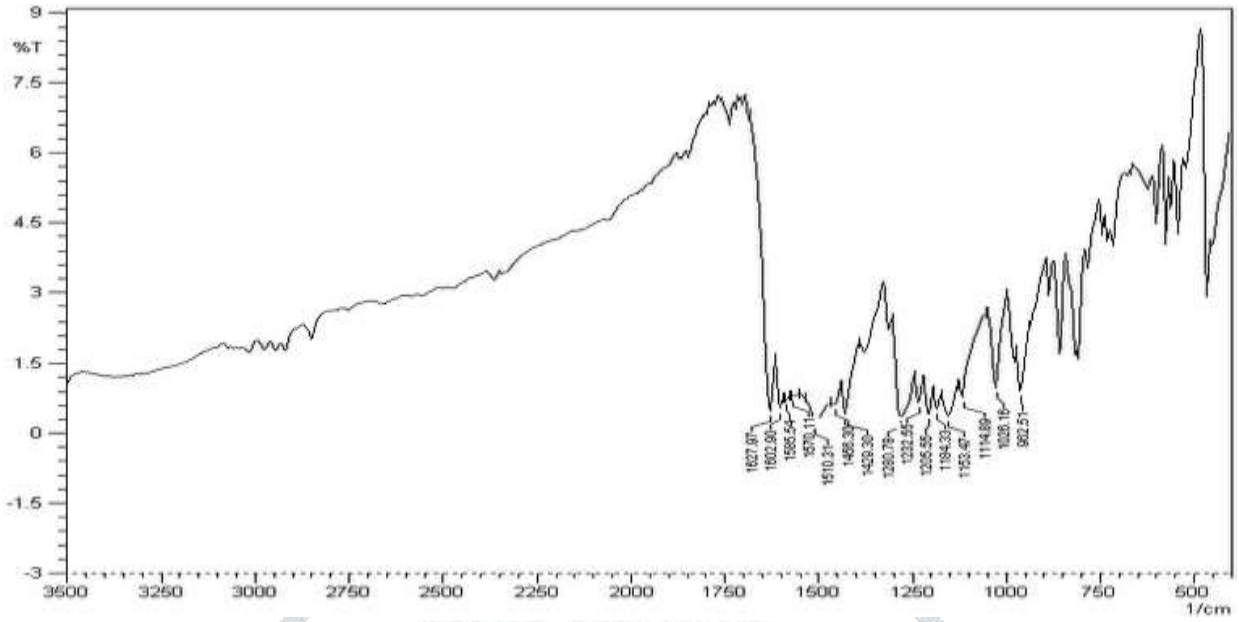

Figure 5.2: FTIR of Curcumin

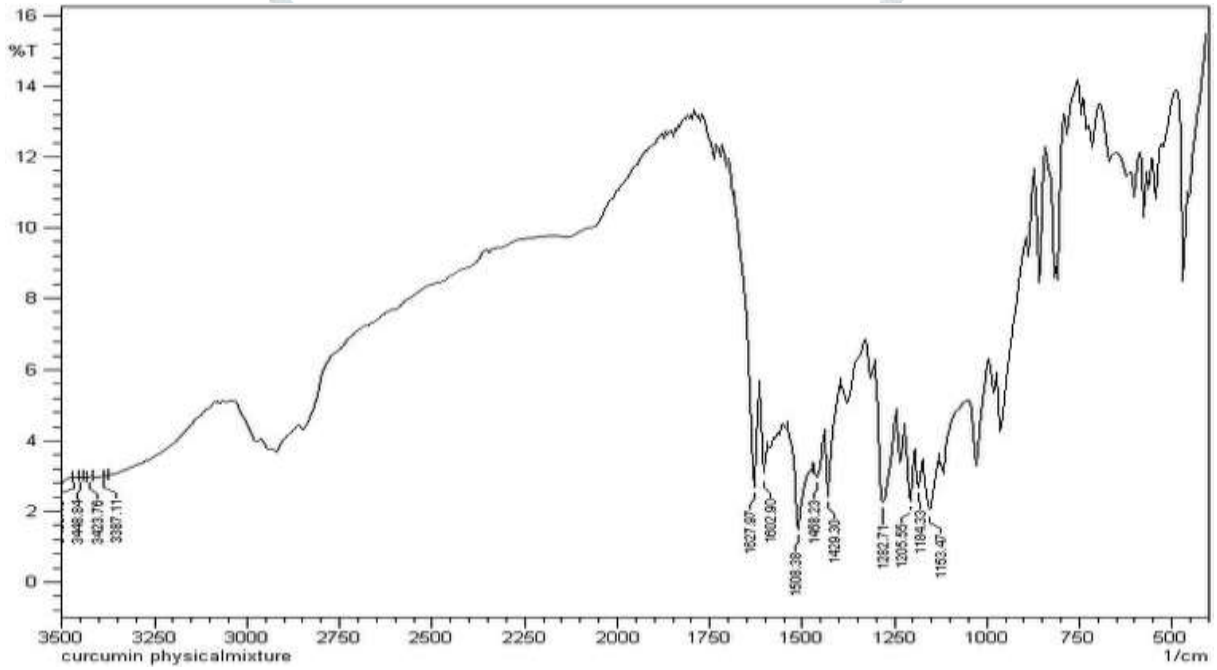

Figure 5.3: FTIR of Curcumin and Physical Mixture

The FT-IR spectroscopy of curcumin, Physcial Mixture was carried out to investigate the incorporation of curcumin in these polymeric nanoparticles. The spectra are given in Figure 5.2 and 5.3. A major peak in all the three spectra at around 1510 cm^{-1} was observed and this was due to OH vibrations of intermolecularly bonded OH groups. The strong peak observed at 1627 cm^{-1} was due to C=O absorption. The C=C functional group appeared at 1602 cm^{-1}indicating the loading of curcumin and further suggested that curcumin was present in physical mixture. All the groups were present at the same value hence drug sample was genuine and free from any major type of impurities.

Analysis by UV-Visible spectrophotometry

Preparation of standard graph

Stock solution of Curcumin : Stock solution of 100 µg/ml was prepared by dissolving 100 mg of curcumin in 100 ml of methanol. Dilution in the range of 10 of 100 µg/ml were scanned for determining λ_{max} from 400-800 through UV spectrophotometer and λ_{max} was found to be at 426 nm for Curcumin.

Preparation of calibration curve in methanol: From this solution of conc. 2 µg/ml, 4 µg/ml, 6 µg/ml, 8 µg/ml, 10 µg/ml were prepared. The linear regression analysis was done on absorbance data points. A straight line generated to facilitate the calculation of amount of drug, the equation is as follows:

$$Y = mx + c$$

Where Y= absorbance, m = slope, x = concentration.

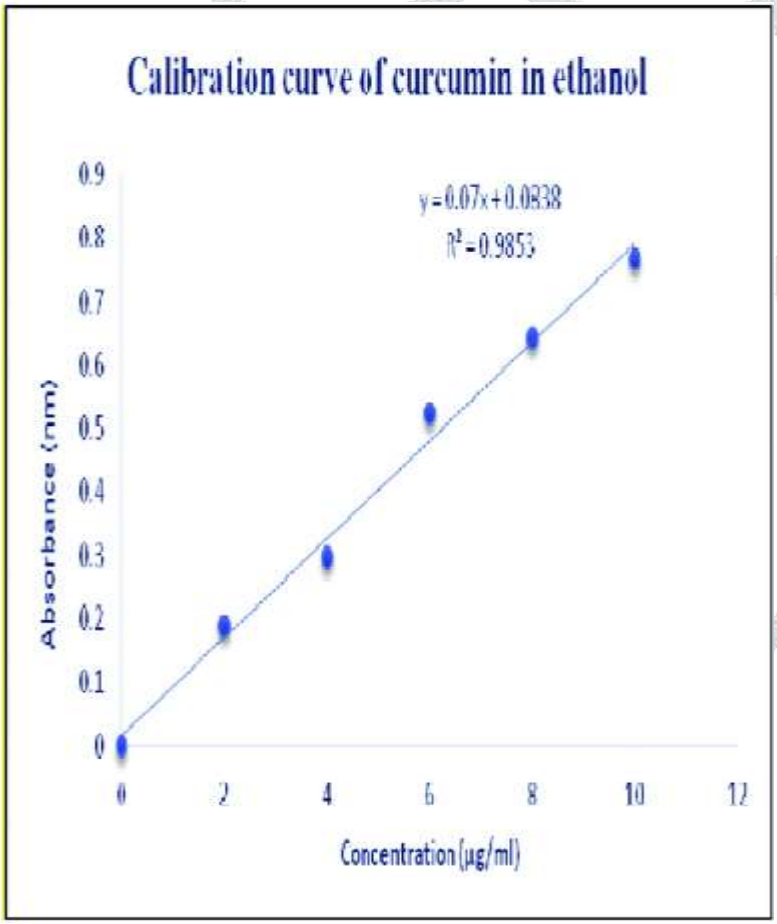

Figure 5.4-: Standard Curve of Curcumin

Table 5.3: Absorbance different dilutions of drug at 426 nm in methanol

S.NO.	Conc. (µg/ml)	Abs.
1	2	0.072
2	4	0.162
3	6	0.253
4	8	0.341
5	10	0.440

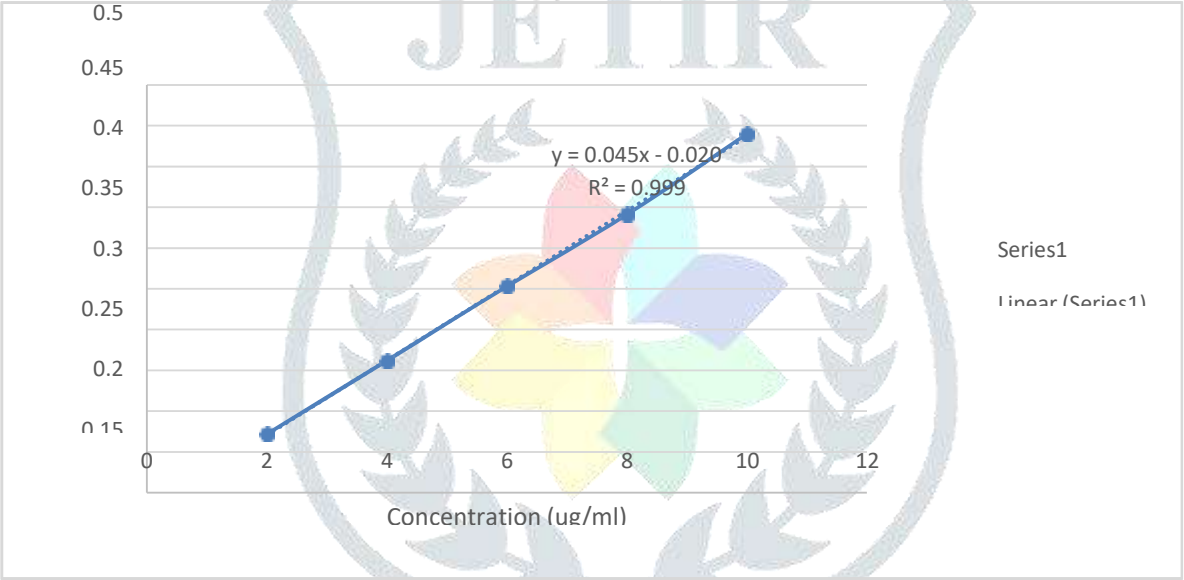

Figure 5.5: Standard calibration curve of Curcumin at 426 nm.

EVALUATION OF NANOPARTICLES

Drug entrapment efficiency

Drug entrapment efficiency was calculated as by formula:

$$\% \text{ Entrapment efficiency} = \frac{\text{Amount of entrapped drug recovered}}{\text{Total amount of drug}} \times 100$$

% E.E. was found to be 59.8%

Transmission electron microscopy (TEM):

Formulation was selected as best formulation and therefore subjected for TEM to obtain the picture of nanoparticles on scale bar of nm with magnification 13.0 x 4000 as shown below. On characterization spherical, unilamellar vesicles with smooth surface were observed under transmission electron microscopy (TEM).

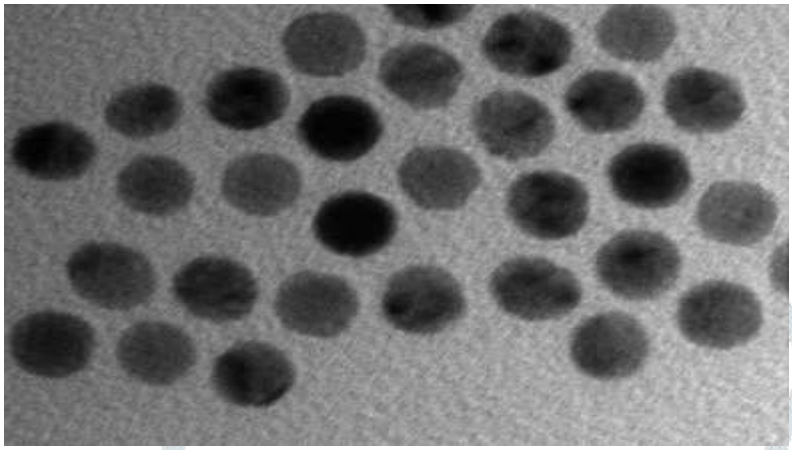

Figure 5.6: TEM of nanoparticles

Zeta potential measurement:

The Z avg. diameter computed by the equipment software was reported to be 358 nm with pdi of 0.543. Zeta potential (Fig. 7.10) measured by the instrument was found to be approx. zero, i.e., -0.0462 mV.

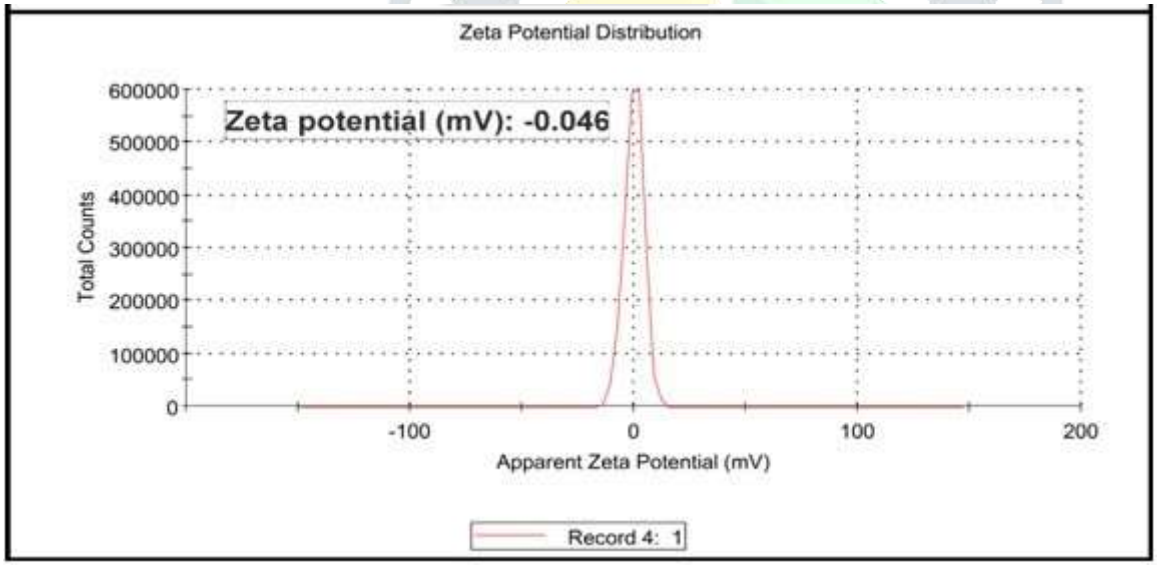

Figure 5.7: Zeta potential nanoparticles

Particle size measurement:

Figure 5.8: Particle size Nanoparticles

The data were processed by cumulants analysis of the experimental correlation function and vesicle diameters were calculated from the computed diffusion coefficients using the Stokes- Einstein equation. Two peaks (Fig.5.9) have been determined by the zeta sizer, the first at 87.1% intensity (corresponding to 715.4 nm size) and second at12.7% intensity (corresponding to 87.46 nm size).

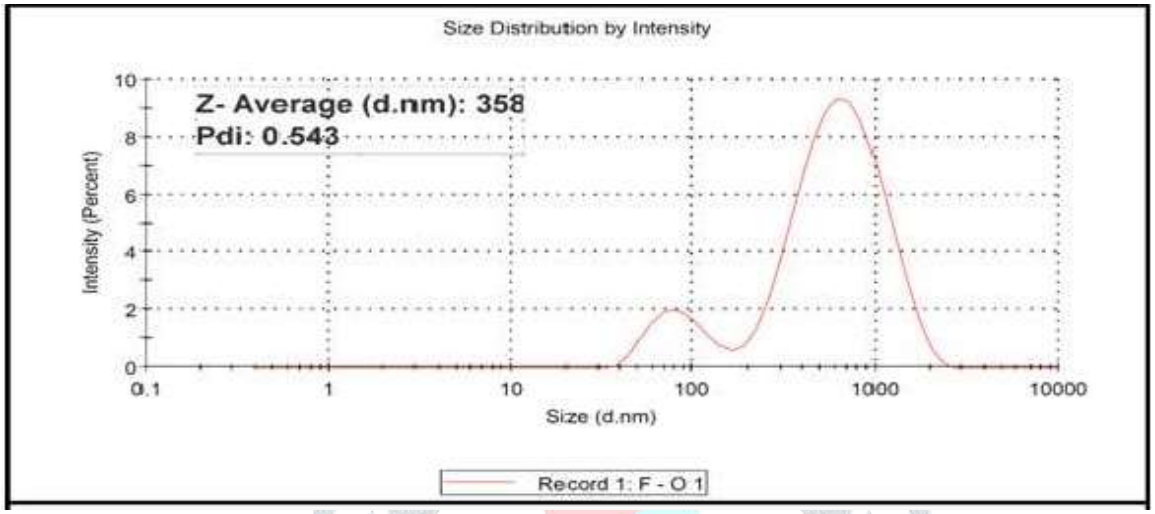

Figure 5.8: Particle size Nanoparticles

X- ray diffraction (XRD)

X-Ray Diffraction studies were carried out for C-NPs and curcumin to understand the nature of curcumin in C-NPs (Figure 5.10). The characteristic peak of curcumin was bserved in the 2 Θ range of 10-30 ºC, indicating the high crystalline nature of curcumin.

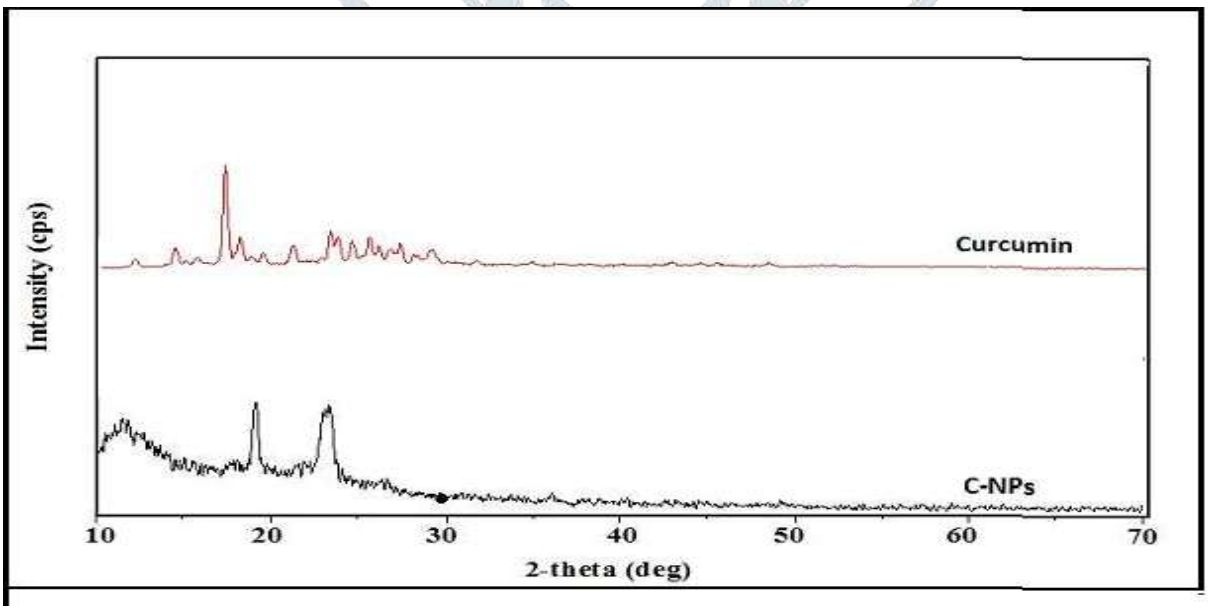

Figure 5.9: X-ray diffraction of Curcumin and Curcumin nanoparticles

Antimicrobial activity

Antibacterial activity of aqueous and solvent extracts was determined by agar well diffusion method according to National Committee for Clinical Laboratory Standards (NCCLS) Inoculum containing 10^6 cfu/ml of Staphylococcus aureus bacterial culture to be tested was spread on Mueller Hinton agar plates With a sterile Swab moistened with the bacterial suspension. Subsequently, wells of 8 mm diameter were punched into the agar medium and filed with 100 µl(.._mg/ml) of medicine prepared in acetone and allowed to diffuse at room temperature for 2 h. Inoculum containing 10^6 cfu/ml of Pseudomonas aeruginosa bacterial culture to be tested was spread on Mueller Hinton agar plates with a sterile swab moistened with the bacterial suspension. Subsequently, wells of 8 mm diameter were punched into the agar medmm and filled with 100 µl (.._. mg/ml) of medicine prepared in acetone and alloved to diffuse at room temperature for 2 h.

The plates were then incubated in the upright position at 37° for 24 h. Wells containing the 100 µl of acetone served as negative controls. After incubation, the diameters of the growth inhibition zones were measured in mm. Three replicates were carried out for each extract against each of the test organism. Data were expressed as mean.

Figure 5.10 : Antibacterial activity of Curcumin and Curcumin nanoparticles against Staphylococcus Aureus

Antibacterial activity of Curcumin and nanoparticles against *Staphylococcus aureus* and *Pseudomonas aeruginosa*

Result of Curcumin	Zone of Inhibition
Staphylococcus aureus	4cm
Pseudomonas aeruginosa	4.5cm
Result of Nanoparticles	Zone of Inhibition
Staphylococcus aureus	6cm

Pseudomonas aeruginosa	5cm

Figure 5.11 : Antibacterial activity of Curcumin and Curcumin nanoparticles against *Pseudomonas Aeruginosa*

Conclusion

The present work on the preparation of Curcumin Nanoparticles is an attempt to utilize the potential of NPs as a carrier to increase the activity of Curcumin. So, we developed and evaluate the NPs containing Curcumin to obtained the optimized formulation with increased antibacterial activity.

Curcumin dosage to treat specific diseases is still a goal for researchers. If we want the long-term health benefits of this antioxidant, it must be able to enter the bloodstream. NPs formulation of Curcumin alters the chemical structure of Curcumin and it becomes active against resistant bacteria.

The NPs containing Curcumin were prepared and evaluated. Following major objectives have been successfully achieved:

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