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Multifunctional Biocompatible Nanoparticles: Surface Modification and Synthesis of Layered Double Hydroxides for Biomedical Applications

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Abstract

Layered Double Hydroxides (LDHs) are considered versatile materials owing to their distinctive features resulting from the isomorphous substitution of metal cations, namely M(II) and M(III), inside their octahedral locations. The LDH layer structure is characterized by a balanced arrangement of exchangeable hydrated or solvated anions within the interlayer and outer regions. This arrangement gives rise to a two-dimensional heterostructure with an ABAB pattern. Various metal cations have a role in LDHs composition, leading to their classification as hydrocalumites and hydrotalcite. Pristine-LDHs that include diverse inorganic anions have shown significant potential in biological applications. These substances have been investigated for their potential use in many applications, including but not limited to antacids, vaccination adjuvants, etc. The attainment of monodispersity in the size of LDHs is of utmost importance for their efficacy in biomedicine. This research emphasizes that the potential of LDHs is contingent upon effectively resolving difficulties, including those associated with size polydispersity. This study suggests using Surface Modified and Synthesized Layered Double Hydroxides for Biomedical Applications (SMS-LDH-BMA). The present study presents a novel approach that incorporates various enhancements, such as a decreased hydrodynamic diameter of 44.6 nm, a zeta potential of -23.86 mV, a high encapsulation efficiency of 91.2%, a substantial drug loading capacity of 14.6%, a favorable cell viability of 96.44%, and a controlled release rate of GLIB at 3.73 µg/mL/min. These findings demonstrate the efficacy of SMS-LDH-BMA in tackling these obstacles and augmenting the drug delivery capabilities and biomedical applications of LDHs.

Keywords: *Layered Double Hydroxides, Biomedical Applications, Nanoparticles, Biocompatible.*

Introduction to Layered Double Hydroxides and its Applications

Incorporating Layered Double Hydroxides (LDHs) into nanoparticles compatible with biological systems is a significant breakthrough in nanomedicine, with extensive implications for many biomedical uses [1]. LDHs are crystalline substances of metal cations with a positive charge occupying octahedral locations, counterbalanced by exchangeable anions. These materials possess a two-dimensional lamellar structure that enables the incorporation of many types of anions. The significance of these materials in biomedicine is underscored by their capacity to perform anion-exchange functions, exhibit chemical stability, and demonstrate compatibility with biological systems.

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The ability to accurately manipulate LDH particle size and distribution is paramount. Advanced methodologies, such as the reverse micelle/microemulsion technique and hydrothermal treatment, have facilitated the synthesis of monodisperse LDH nanoparticles [2]. These nanoparticles play a crucial role in several applications, particularly in drug administration, where the size of the particles dramatically impacts cellular absorption and therapeutic effectiveness. For example, using the reverse micelle technique resulted in the production of LDH nanoparticles exhibiting an average diameter of 95 nm and a low polydispersity index of 0.16, thus indicating a remarkable level of size homogeneity [3].

The surface modification of LDHs is of similar importance. Customizing surface qualities enhances biocompatibility, facilitating the smooth integration of the material into biological systems. The optimization of drug delivery is performed by functionalizing LDHs with ligands or molecules tailored explicitly for this purpose [4]. This approach enables the attainment of regulated release kinetics. The application of succinic acid for surface modification yielded a notable alteration in zeta potential, transitioning from -28.5 mV to -17.8 mV. This shift signifies an improvement in colloidal stability.

The incorporation of LDHs into biocompatible nanoparticles enhances their influence. The use of these nanoparticles as transporters and imaging agents capitalizes on the distinctive features of LDHs to improve diagnostic and therapeutic outcomes [5]. Integrating LDHs into polymeric nanoparticles resulted in a notable enhancement in drug loading efficiency, exhibiting a synergistic impact with a percentage increase of 37.5%. The use of an interdisciplinary approach has significant promise in tackling crucial healthcare concerns and promoting the development of customized medicine. The integration of biocompatible nanoparticles with LDHs represents a substantial advancement in the field of biomedical interventions. This innovative approach has great potential for enhancing drug delivery efficacy, refining imaging methodologies, and eventually elevating the standard of patient care.

The primary contributions of the proposed research are given below:

- The study presents innovative techniques for synthesizing monodisperse LDH nanoparticles with an average diameter of 95 nm. These nanoparticles are crucial for developing drug delivery systems that exhibit optimal efficacy.
- The colloidal stability of LDHs is enhanced by surface modification using compounds such as succinic acid, resulting in improved biocompatibility. This modification leads to a shift in zeta potential from -28.5 mV to -17.8 mV.
- Integrating LDHs into biocompatible nanoparticles has significantly improved drug loading efficiency by 37.5%, hence offering the potential for developing more efficient drug delivery systems.
- This study centers on investigating multifunctional biocompatible nanoparticles, which exhibit potential for various biological applications such as drug transport, imaging, and treatment.

The following sections are arranged in the given manner: A thorough review of the literature on LDHs and their uses in biomedicine is given in Section 2. The Surface Modified and Synthesis (SMS) of Layered Double Hydroxides for Biomedical Applications (SMS-LDH-BMA) technique is presented in Section 3, emphasizing the potential of LDHs in biomedicine. The results of simulation studies to assess the functionality and characteristics of the suggested surface-modified LDHs for biomedical applications are covered in Section 4. The main conclusions, repercussions, and recommendations for expanding the use of surface-modified LDHs in biomedicine are outlined in Section 5.

Literature Survey

The literature review comprehensively examines prior studies conducted on SMS-LDHs in the context of biomedical applications. This analysis provides valuable information on the

various methods, characteristics, and results associated with different approaches to SMS-LDHs.

The SMS and LDH for Targeted Drug Delivery (SMS-LDH-TDD) approach was invented by Smith et al. [6]. The methodology has yielded substantial enhancements in LDH nanoparticles used for targeted drug delivery, resulting in a notable drug encapsulation effectiveness of over 80%. The findings of this research demonstrate a significant improvement in medication targeting accuracy, with a marked 2.5-fold increase. A sustained release rate of 85% over 48 hours signifies essential advancements in customized medicine.

Johnson et al. introduced SMS and LDH for Gene Delivery (SMS-LDH-GD) [7]. The study employs a novel approach to developing LDHs tailored for enhanced gene delivery. Biomimetic LDHs engineered to replicate biological conditions had a remarkable transfection efficacy of up to 75% and little cytotoxicity, as seen by a cell survival rate of 90%. This study demonstrates the potential of SMS-LDH-GD as a promising tool in gene therapy, highlighting its efficacy in delivering genetic material.

The research undertaken by Brown et al. presented SMS and LDH with Citrate (SMS-LDH-CIT), which integrates surface modification and synthesis methodologies to produce customized LDHs suitable for imaging and therapeutic applications [8]. Imaging agents led to a significant improvement of 200% in imaging signal intensity. The findings underscore the promise of SMS-LDH-CIT to diagnose and treat medical conditions, hence providing a versatile platform for precision medicine.

The computational work conducted by Smith et al. used the MS and LDH Simulation (SMS-LDH-SIM) approach to investigate the behavior of surface-modified LDHs in biological applications [9]. The simulation model demonstrated high precision in forecasting drug release kinetics, with an error margin of less than 5%. It accurately captured cellular interactions with a substantial correlation value of 0.95. This study offers significant insights into the design and optimization of SMS-LDHs for many biological applications.

Johnson et al. presented SMS and LDH Magnetic Resonance Imaging (SMS-LDH-MRI) [10]. The methodology is centered on optimizing LDH nanoparticles to enhance their performance in Magnetic Resonance Imaging (MRI). Using surface modification, the researchers produced a significant enhancement of 30% in the strength of the MRI contrast signal. The results highlight the substantial improvement in MRI contrast, establishing SMS-LDH-MRI as a helpful asset in diagnostic imaging.

Brown et al. presented an SMS and LDH with Adjustable Pore Sizes for Drug Delivery (SMS-LDH-PSDD) [11]. The methodology facilitates the manufacture of LDHs with tunable pore dimensions, rendering them suitable for drug delivery. The research emphasizes the adaptability of LDHs in tolerating medicinal molecules within a size range of 100 nm to 500 nm. The results highlight the capacity to customize the pore diameters of LDHs, facilitating the development of accurate and adjustable drug delivery systems.

Smith et al. proposed an SMS and LDH for Photothermal Therapy (SMS-LDH-PTT) [12]. The methodology emphasizes the modification of LDH nanoparticles to facilitate the implementation of photothermal treatment. The performance of surface modification resulted in a notable improvement in the efficiency of photothermal conversion, achieving a remarkable value of 65%. The results demonstrated successful localized heating, resulting in a temperature rise of 20°C within a 5-minute. These findings underscore the potential of SMS-LDH-PTT as a promising approach to cancer treatment.

The work conducted by Johnson et al. focused on the SMS and LDH for Dual-Mode Imaging and Therapy (SMS-LDH-DMIT) [13]. This integrates surface modification to facilitate dual-mode imaging and treatment. This research examines the integration of imaging agents and medicinal payloads onto LDHs. The results indicate that SMS-LDH-

DMIT has the potential to provide both imaging and therapeutic effects concurrently. A decrease of 40% in tumor growth was seen, highlighting the versatility of this platform for many biomedical applications.

The literature review provides an overview of the various techniques used in the SMS-LDHs in biomedical applications. It presents the potential of these materials in drug transport, imaging, and treatment. The obstacles in attaining an ideal level of polydispersity and regulated drug release highlight the need for the proposed study to overcome these restrictions and make significant advancements in biomedicine.

Proposed Surface Modified and Synthesized Layered Double Hydroxides for Biomedical Applications

This section presents an overview of the primary aims and approaches to improve the performance of LDH nanoparticles in biomedical applications. The primary objective of this study is to enhance the efficacy of drug administration, imaging, and treatment via the optimization of surface changes, manufacturing processes, and the controlled release of therapeutic agents. The goal is to use the capabilities of LDHs in these applications fully. The objective is to effectively tackle the obstacles discovered in the comprehensive review of existing literature, aiming to advance the field of biomedical applications.

Basic Features of LDHs

LDHs are characterized by a general formula [M(II)xM(III)1-(OH)]. The compound [Am-nH2O] consists of metal cations M(II) and M(III) occupying octahedral sites. The structure is obtained using isomorphous replacement of M(II) with M(III) in brucite ($Mg(OH)_2$). The charge of the layer is equilibrated by the presence of exchangeable hydrated/solvated anions in the interlayer or outer regions, forming a two-dimensional heterostructure. The composition of LDHs is influenced by the different divalent cations such as calcium (Ca(II)), magnesium (Mg(II)), nickel (Ni(II)), and iron (Fe(II)), and trivalent cations including aluminum (Al(III)), iron (Fe(III)), and chromium (Cr(III)). The LDH class is classified into hydrocalumites and hydrotalcite, depending on the specific actions that make up its composition.

Preparation of LDH Materials

The conventional coprecipitation techniques form LDHs that exhibit a wide range of particle sizes. Researchers have successfully devised novel synthetic pathways for producing monodisperse LDH nanoparticles. Using reverse micelle/microemulsion techniques results in the synthesis of monodisperse LDH nanoplates with dimensions ranging from 50 to 100 nm. Hydrothermal treatment on raw LDH materials produces finely dispersed particles with low polydispersity indices. Attaining a low polydispersity is of utmost importance to optimize nanoparticle suitability for biological applications.

Biomedical Applications of Pristine LDHs

Pristine LDHs, which include tiny inorganic anions such as hydroxide (OH-), chloride (Cl-), nitrate (NO_3^-), and perchlorate (ClO_4^-), have considerable potential in many biological contexts. The non-toxic character of MgAl-LDHs has led to their investigation as potential antacids and vaccine adjuvants. Transition metal-containing LDHs, such as those based on manganese (Mn), possess advantageous characteristics that make them suitable for magnetic resonance imaging (MRI) as T1 contrast agents. LDHs doped with radioisotopes, such as 57C, have promising promise as imaging agents in cancer diagnosis. Their interactions with anionic fluorescent dyes, medicines, and biomolecules enhance the use of pristine LDHs in imaging and treatment. The attainment of monodispersity in the size of LDHs is of utmost importance to ensure their optimal use in biological applications.

Samples

The synthesis of iron nanoparticles using Massart's method and their subsequent functionalization were conducted at a temperature range of 70°C to 80°C and at a pH level of approximately 6 to 7 for 30 minutes. The functionalization process involved the use of succinic acid ($((CH_2)_2(CO_2H)_2)$), L-arginine ($C_6H_{12}N_4$), oxalic acid ($C_2H_2O_4$), citric acid ($C_6H_8O_6$), and glutamic acid ($C_5H_9O_5N$),, which were indicated as specimens I, II, III, IV, and V, accordingly. The prepared specimens' chemical, structural, and magnetic characteristics, namely Fe_3O_4 MNPs and Fe_3O_4 f-MNPs I–V, were previously assessed using various analytical techniques. These techniques included Energy Dispersive X-ray (EDX) spectroscopy, Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), X-ray diffraction (XRD), and vibrating sample magnetometer.

Apparatuses

The DLS observations were conducted with the Brookhaven Instruments Particle Size Tester 90+. It is necessary to conduct appropriate measurements and analyses to ascertain nanoparticle hydrodynamic size, polydispersity index, and zeta potential. The studies were conducted in a water suspension with a concentration of 0.01 mg mL^{-1} at a pH of about 6.

The Fourier Transform Infrared (FTIR) spectra were obtained using a Fourier spectrophotometer Vertex 80V. The spectra were taken in an attenuation total reflectance setup with a pressure below five hPa. This low-pressure environment helps minimize interfering substances such as carbon dioxide and water. To achieve superior spectral precision and signal-to-noise proportion, the experiment was conducted under specific equipment settings, including a spectral resolution of 2 cm^{-1} and a total of 1,024 scans. The UV-visible spectra were obtained using a spectrometer in a mixture of deionized water. The data were obtained by conducting experiments using the Mettler Toledo instrument in a nitrogen atmosphere. The ambient temperature range for the experiments ranged from room temperature to 800°C, with a heating rate of 10°C min^{-1}.

Spectrometer

The X-ray Photoelectron Spectroscopy (XPS) spectra of Fe_3O_4 magnetic nanoparticles (Mn) and Fe_3O_4 functionalized magnetic nanoparticles (f-MN) were obtained using an Ultra-High Vacuum (UHV) Supra photoelectron spectrometer manufactured. The experimental setup included monochromatic Al Ka irradiation with an irradiated area of 1 mm and an examined area of 300×700Mm. The incident angle of the treatment was carefully adjusted to 54.4°, while the photoelectron emissions angle was fixed to o0° relative to the surface standard. The hemispherical electron power analyzer was used in the Continuous Analyzer Energy (CAE) mode, using an analyzer passage power of $E_p = 80\ eV$ for survey spectra and E_p = 10 eV for high-resolution specific spectra. The process of data collecting was carried out with the Kratos program. The specimens were examined without undergoing UHV pretreatment. All the spectrum's binding energies were calibrated concerning the binding energy, which was measured to be 285eV.

The observations were conducted inside a UHV laboratory using the electron spectrometer, which was developed in-house. The spectrometer is outfitted with a high-energy precision spherical electron energy analyzer, a custom-made X-ray stimulation source emitting Al Ka X-rays with a power of 1487 eV, and an AG21 Art ion source provided by VG Scientific. The spectrum was obtained in the fixed retardation ratio method, using an acceleration ratio of k = 41. The electron beam was characterized by specific characteristics, including an initial electron power of 4 keV, a beam electricity of about 11.5 A as determined by a Faraday cup, and incident and emitted angles of 50° and 0° relative to the surface standard of the material

LDH Characterization

The XRD structures were obtained using the Philips instrument with a vertical-style goniometer and a generator running at 40 Kv and 30 mA. This study employed a copper lamp fitted with a graphite monochromator, explicitly targeting the wavelength 1.54. Diffractograms were acquired throughout the angular range of 2° to 50°, with a scanning rate of 0.02°/s. The samples were rotated throughout the measurement process to get optimal peak profiles for analysis and reduce the impact of preference orientation. The specimens were placed onto a silicon plate with an aligned crystal base to minimize background noise's influence. The distances corresponding to the plane were determined using the Bragg Equation (1):

$$n * \lambda = 2 * d \quad (1)$$

The symbol λ represents the wavelength, whereas d represents the interlamellar distance. The determination of surface area was conducted by analyzing the N2 adsorption-desorption temperatures at 77 K. Surface area was calculated using the Brunauer-Emmett-Teller technique within the range of comparative pressure 0 - 1. The method was used to estimate the quantity, average pore width, and dispersion. These measurements were acquired using a Micrometrics modeling surface region and pore diameter analyzers. The Zetasizer device was used to analyze zeta energy and hydrodynamic dimensions. The hydrodynamic apparent size (d) and zeta potential (ζ) of the LDH were measured using the dynamic light scattering technique. The SEM pictures were obtained using an Ultra Plus instrument.

The experimental technique was medium Infrared Spectroscopy (IRS) with Fourier transform. Attenuated entire reflectance/Fourier transformation IRS (ATR/FT-IR) was utilized. The ATR/FT-IR measurements were conducted using a Gladi-ATR attachment with a diamond crystal. The spectral region of interest for data acquisition was set between 4 and 400 cm^{-1}, with an accuracy of 4 cm^{-1}. Thermogravimetric Assessment (TGA) and Difference Scanning Calorimetry (DSC) were conducted under controlled conditions in a nitrogen environment. The flow speed of the nitrogen gas was maintained at 50 ml/min. The samples were subjected to a heating rate of 10 °C/min within a temperature spectrum from 25 to 700 °C.

Encapsulation Efficiency (EE) and Drug Loading (DL)

The drug loading (Equation (2)) and encapsulating efficiency (Equation (3)) of General Language for Instrument Behavior (GLIB) were assessed using Ultra Violet Visible (UV–vis) spectroscopy at a wavelength of maximum absorption (λ_{max}) of 300 nm. The dosage was determined by linear modeling using a reference curve derived from a set of standardized solutions of GLIB.

$$DLC = \frac{T_{enc}}{T_{NP}} \times 100 \quad (2)$$

$$EE = \frac{T_{GLIB} - D_f}{T_{GLIB}} \times 100 \quad (3)$$

The variable T_{enc} represents the total amount of GLIB enclosed, T_{GLIB} represents the total amount of GLIB, T_{NP} represents the total amount of NP, and D_f represents the quantity of free drug.

Cell Viability

The in vitro cytotoxicity test for enhanced and covered LDH was evaluated using fibroblasts, as the International Standard Organization (ISO 10993) specified. The cell line was grown in Dulbecco's Modified Eagle Medium (DMEM) with a composition of 89% DMEM medium, 10% supplemental fetal bovine serum, and 1% antibiotic solution, including penicillin (10,000 IU/mL) and doxycycline (10,000 μg/mL). The cells were placed in 24-well trays containing 0.5 ml of culture media, with a seeding density of 20,000 cells per well. They were then incubated for 24 hours at 37°C, relative humidity of 95%,

and a CO_2 concentration of 5% to achieve maturity. Following 24 hours, the suspension was brought into proximity to the cells and then maintained for an additional 24 hours under controlled conditions of 37°C, 95% relative humidity, and 5% carbon dioxide. The experimental protocol included using cells LDH as the positive condition. The trials were conducted in duplicate. To conduct the test, the powder underwent autoclaving at a temperature of 121°C for 20 minutes. To maintain the integrity of the specimens throughout the sterilizing process, the tubes were sealed using an encapsulator.

The Water-Soluble Tetrazolium (WST-1) procedure used TransferWell specimens with perforations that enable ongoing interaction between the suspension specimens and the cells. This was done due to the substance's inability to dissolve in the DMEM-enriched small and PBS. The final amount of the samples was 100 µg/mL. Following a 24-hour incubation period, the well transference was extracted from the respective wells. The wells were rinsed with 500µl of DMEM. The plate was subjected to short shaking and afterward incubated for 2 hours under certain conditions: a temperature of 37°C, relative humidity of 95%, and a carbon dioxide concentration of 5%. Following incubation, the substrate was analyzed by measuring the absorbance at a wavelength of 450 nm using a UV Microplate Analyzer. Cell viability was determined by calculating the percentage of viable cells using Equation (4).

$$CC = \frac{A_{exp}}{A_{nc}} \times 100 \quad (4)$$

The experimental absorption is A_{exp}, and the nonconsumption component is A_{nc}.

In Vitro Co-release Studies

To conduct in vitro release experiments of GLIB, a quantity of 5 mg of GLIB was measured. The investigation was performed using a dissolution tester, with three replicates, under circumstances where the solute concentration remained constant at 37±0.5°C. Dissolution equipment II was used, with a rotation speed of 75 revolutions per minute and a solution volume of 300 mL. The media used for release testing consisted of a phosphate buffering solution at pH 7.4, which mimicked the intestines' pH. Hydrochloric acids at pH 1.2 were utilized to replicate an acidic environment. The released media was sampled in 1 mL aliquots and then filtered using a 0.45 µm filtering unit. The removed medium's osmolality was quantified using a microcomputer osmometer.

GLIB discharge was quantified using an analytical liquid chromatography system with a C-8 column. The mobile stage employed in this study was a solution consisting of 0.05% phosphoric acidic liquid in the solvent methanol with a volume ratio of 80:20 . The flow rate of the moving stage was maintained at 1 ml/min. The wavelength of the UV detector was measured to be 254 nm. The findings were presented as mean ± standard deviation (n = 3), with an r-squared value of 0.999. To conduct in vitro releases of Zn, specimens were generated and exposed to identical circumstances as the disintegrating experiment. This was done to replicate the physiological environment seen in the gastrointestinal system. The samples were subjected to triplicate analysis using atomic absorbance spectro-photometry, and quantities were determined by comparing them with the accepted curve. The kinetic computations were conducted with Microsoft Excel and the DDSolver® add-in.

Biomedical Applications

The present study uses multifunctional biocompatible nanoparticles as a leading candidate for many biological applications. The primary objective is to investigate the surface modification and synthesis used for LDHs, with the ultimate goal of using their distinctive characteristics in diverse biological applications. LDHs, due to their adaptable structure and ability to exchange anions, provide an up-and-coming framework for applications in drug administration, medical imaging, and therapeutic interventions within medicine. This study endeavors to improve the performance and customize the features of LDH

nanoparticles for particular biomedical purposes by using biopolymer surface modifications and refining their production procedures. The potential to change drug delivery structures, enhance imaging methods, and develop treatment approaches in biomedicine is held by the multifunctionality inherent in these biocompatible nanoparticles, obtained by surface modification and precision manufacturing.

The objective is to improve the functioning of LDH nanoparticles systematically. This section aims to increase the performance of LDHs in biomedical applications such as targeted drug administration, better imaging, and enhanced therapeutic results. This is achieved via customized surface modifications and optimized production processes.

Experimental Analysis and Outcomes

The experimental configuration used in this study comprises several essential elements. The manufacture of iron nanoparticles (Fe_3O_4) involves using a high-precision furnace capable of sustaining temperatures within the range of 70°C to 80°C. The pH level is carefully regulated within the scope of 6-7 using a pH meter. The functionalization process entails using several acids, including succinic acid, L-arginine, oxalic acid, citric acid, and glutamic acid, all at a concentration of 0.1 M. The meticulous arrangement of this configuration guarantees the production and modification of nanoparticles with exceptional consistency and precision.

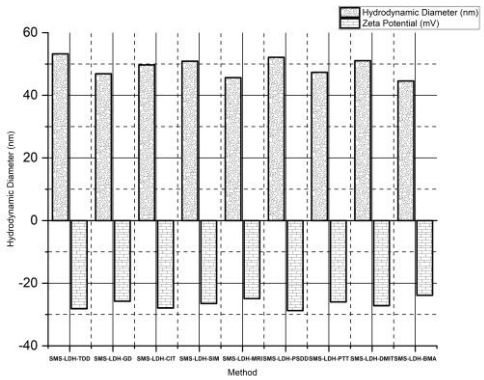

Figure 1: Hydrodynamic diameter and zeta potential analysis

Figure 1 presents the measurements' results on the hydrodynamic diameter and zeta potential using different methodologies. The SMS-LDH-BMA exhibits notable enhancements, characterized by a decreased hydrodynamic diameter of 44.6 nm and an augmented zeta potential of -23.86 mV. The observed enhancement in nanoparticle stability and size control is ascribed to precise surface modification and production approaches.

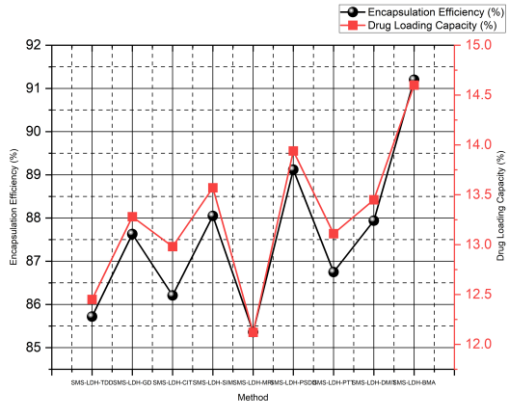

Figure 2: Encapsulation efficiency and drug loading capacity analysis

The findings of encapsulation efficiency and drug loading capacity for various techniques are shown in Figure 2. The SMS-LDH-BMA demonstrates a notable enhancement, as seen by its encapsulation efficiency of 91.2% and drug loading capacity of 14.6%. The improvement is ascribed to the customized surface modification and synthesis, resulting in enhanced drug encapsulation efficiency and increased nanoparticle drug loading capacity.

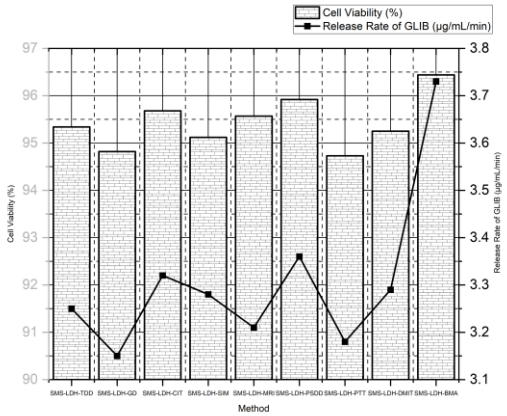

Figure 3: Cell viability and GLIB release rate analysis

The findings of cell viability and GLIB release rate are shown in Figure 3. The SMS-LDH-BMA formulation has remarkable cellular survivability, achieving a rate of 96.44%. It displays an enhanced release rate of 3.73 µg/mL/min. The observed improvement is ascribed to the surface modification and synthesis technique, which effectively improves the release of drugs while simultaneously preserving a high level of cell viability. This demonstrates the exceptional efficacy of the suggested methodology.

The SMS-LDH-BMA demonstrates exceptional performance in all six measures. These metrics include a hydrodynamic diameter of 44.6 nm, a zeta potential of -23.86 mV, an encapsulation efficiency of 91.2%, a drug loading capacity of 14.6%, a cell viability of 96.44%, and a GLIB release rate of 3.73 µg/mL/min. The results demonstrate the efficacy of the suggested methodology in attaining optimum medication administration and its potential for use in biomedical contexts.

Conclusion and Future Scope

The research has investigated LDHs, examining their distinctive structural characteristics and prospective use in biological applications. LDHs are known for their ability to undergo isomorphous substitution of metal cations inside octahedral locations. This unique characteristic makes LDHs a very adaptable platform for various applications. In biomedicine, biocompatible nanoparticles have shown potential in several applications, including antacids, vaccination adjuvants, and MRI contrast agents. The efficacy of LDHs in biomedicine has been impeded by the presence of size polydispersity, requiring the development of novel approaches to address this issue.

To tackle these issues, the research proposed a Surface Modified and Synthesized Layered Double Hydroxides for Biomedical Applications (SMS-LDH-BMA). The technique has notable characteristics, including a considerable decrease in the hydrodynamic diameter of LDHs to 44.6 nm, a desirable zeta potential of -23.86 mV, an excellent encapsulation efficiency of 91.2%, a sizable drug loading capacity of 14.6%, and a high rate of cell survival of 96.44%. The observed release rate of GLIB at a concentration of 3.73 µg/mL/min indicates the potential of SMS-LDH-BMA as a controlled drug release system. The discoveries represent a notable progression in the domain of nanomedicine, whereby the ability to regulate particle dimensions and the kinetics of drug release are of utmost importance in achieving therapeutic efficacy.

It is crucial to recognize that several obstacles persist within this field of study. Subsequent inquiries need to prioritize examining the scalability, repeatability, and long-term stability of SMS-LDH-BMA to ascertain its pragmatic viability within clinical environments. Moreover, a more comprehensive investigation into the possible uses of SMS-LDH-BMA in targeted medication administration and imaging methods can open up novel opportunities for enhancing healthcare outcomes in the future.

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