Research Article

Preparation, Characterization, and In Vitro Performance of Gambogenic Acid-Layered Double Hydroxide/Liposome Nanocomposites

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Gambogenic acid (GA) refers to a xanthonoid that exhibits significant antitumor activity due to its poor solubility and low bioavailability. For this reason, its shortcoming should be overcome using novel approaches to improve its practical effectiveness. In this study, with the use of ion exchange method, GA was encapsulated in layered double hydroxide (LDH). In the GA-LDH nanohybrid, GA was distributed and stabilized in the interlamellar region of LDH through intermolecular interactions. GA-LDH was further modified by liposome (LS) through ethanol injection method. The drug encapsulation efficiency of GA-LDH/LS was obtained as 56.28%. The chemical structures and physicochemical properties exhibited by GA-LDH/LS were characterized and confirmed using different instruments, and drug release showed that GA-LDH/LS had significantly sustained release due to the combined effect of the matrix LDH and the phospholipid bilayer. Furthermore, GA-LDH/LS displayed lower hemolysis percentage than GA-LDH during the hemolysis test. This study suggested that GA-LDH/LS nanocomposite could be a promising antitumor drug delivery system due to its outstanding performance in biomedical research.

1. Introduction

Gambogenic acid (GA) has been employed for centuries for the treatment of infections and tumors, which is a xanthonoid that is separated from the exudates of Garcinia hanburyi Hook f. (Clusiaceae) [1]. GA has a wide range of anticancer activities [2, 3]. Its anticancer effect is different from that of chemotherapeutic anticancer drugs. GA is capable of selectively killing cancer cells without affecting normal hematopoietic cells and leukocytes [4]. However, impacted by the extremely low solubility of GA in water and poor bioavailability, its clinical application is limited. At present, GA has been generally employed through injection. The long-term use of injection cosolvents or solubilizers may result in several adverse reactions (e.g., allergy, cardiovascular toxicity, nephrotoxicity, and neurotoxicity) [5]. There have some reports on nanoformulations of GA, such as polymer micelles and liposomes [6–9].

Layered double hydroxides (LDH) refer to a class of inorganic layered nanomaterials assembled by the noncovalent interaction of positively charged host layer and interlayer anions [10], termed hydrotalcite-like compounds. LDHs are a family of anionic clays, characterized by [M (II)\(_{1-x}\)M(III)\(_x\)(OH)\(_2\)]\(^{x+}\)[(A\(_{x/n}\))\(^n\)\(^{-}\)]\(^m\)S. Divalent (M(II)) and trivalent (M(III)) metal cations (generally Mg and Al) constitute the clay layers, which take up the octahedra center with hydroxide ions at the vertices [11]. LDH can be employed as a delivery host depending on the superior structural properties. Moreover, LDH has some special features (e.g., high ion exchange and sorption capacity and good degradability) [12, 13], thus making it suitable for drug delivery and protecting the drug from decomposition or denaturing, etc. It was reported [14] that 5-fluorouracil (5-FU) was incorporated into LDH interlayers, and 5-FU-LDH nanohybrids exhibited high blood clearance, sustained releasing, prolonging drug half-life, and increasing...
drug accumulation in target tumor tissues. When methotrexate (MTX) was also inserted into LDH [15], its stability was enhanced significantly through electrostatic interaction. The efficacy of MTX-LDH nanohybrid was nearly 5000 times that of pure drug. The above studies provide fundamentals for LDH-based inorganic material drug delivery systems.

Liposome (LS) is mainly composed of phospholipid bilayer membrane, which has many advantages such as targeting and biocompatibility [16, 17]. A hierarchical and efficient drug delivery system existing as nanocomposites can be developed, using liposomes as protective shells and using drug-LDH nanohybrids encapsulated into the liposome as the core skeleton [18, 19].

In this study, LDH and GA-LDH were synthesized using the hydrothermal method and following ion exchange method. GA-LDH/LS was formed by assembling with liposomes (assembly process was shown in Figure 1), which would combine the advantage of liposomes with LDH to control drug release. The preparation method of GA-LDH/LS nanocomposites was studied. The structure and physicochemical properties exhibited by GA-LDH/LS nanocomposites were characterized and analyzed. The release behavior and hemolytic effect of GA-LDH/LS nanocomposites in vitro were examined.

2. Materials and Methods

2.1. Materials. Sodium hydroxide (NaOH, analytical reagent (AR)), aluminum chloride hexahydrate (AlCl3·6H2O, AR), and magnesium chloride (MgCl2, AR) were purchased by Shanghai Aladdin Reagent Co., Ltd. in China. Gambogic acid (GA, 99% purity) was originated from Nanjing Chunqiu Bioengineering Co., Ltd. in China. Lecithin (99% purity) was offered Shanghai Yuanye Biotechnology Co., Ltd. in China. Cholesterol (AR) was attained from Beijing Bailingwei Technology Development Co., Ltd. in China.

Dichloromethane (AR) and diethyl ether (AR) was provided by Tianjin Jiangtan Chemical Technology Co., Ltd. in China. Ethanol (AR), acetic acid (AR), and methanol (chromatographic reagent, CR) were originated from Tianjin Concord Technology Co., Ltd. in China. Potassium dihydrogen phosphate (NaH2PO4, AR), disodium hydrogen phosphate (Na2HPO4, AR), and phosphoric acid (H3PO4, AR) were sourced from Tianjin Damao Chemical Reagent Factory in China. Water was puriﬁed using a Smart2Pure PRO water puriﬁcation system (Smart2Pure PRO, US).

2.2. Characterization. Fourier transform infrared (FTIR) spectroscopy was performed by utilizing the FTIR spectrometer (Varian 640, USA), KBr tablet, band 400-4000 cm⁻¹. Powder X-ray diffractometer (XRD) patterns were determined by a D/max-řA X-ray diffractometer (MINiflex600, Rigaku, Japan); test conditions: Cu-Kα ray source, voltage 40 kV, current 40 mA, and scanning speed 10/minute. Ultraviolet-visible (UV-vis) measurement was conducted with the spectral range of 200-600 nm by a UV-vis (ALPHA-1506, Shanghai Puyuan Instrument Co., Ltd., China). The GA concentrations in the sample were measured using high-performance liquid chromatography (HPLC) (Shimadzu, Japan). The particle size of the samples was measured using BT-90 Nano Laser Particle Size Analyzer (Dandong Baite Instrument Co., Ltd., China); Zeta potentials of the samples were determined on the basis of zeta potential analyzer (Horiba, Japan). The particle morphologies of the samples were observed under a transmission electron microscope (TEM, JEM-1400; JEOL Ltd., Tokyo, Japan).

2.3. GA-LDH Synthesis. MgAl-LDH was synthesized using the hydrothermal synthesis method [20]. To be speciﬁc, 90.0 mmol of MgCl2 and 30.0 mmol of AlCl3·6H2O were dissolved into 60 mL carbon dioxide-free puriﬁed water. Subsequently, the above salt solution was quickly poured into a basic solution (75 mL) supplemented with 180.0 mmol of NaOH for the precipitation of LDH when the pH of the mixed solution was 10. After being stirred for 24 h in N2 stream at ambient temperature and being aged 3 h, the precipitate was collected through centrifugation and repeatedly cleaned by being redispersed in deionized water, followed by centrifugation. Next, the washed precipitates were dispersed in deionized water and then transferred into a Teflon-lined stainless steel autoclave. Afterward, the hydrothermal treatment was performed at 100°C for 4 h to produce the suspension of LDH. We collected the precipitate through centrifugation and further cleaned repeatedly with deionized water. The washed LDH precipitate was freezing-dried to produce MgAl-Cl LDH powder (simpliﬁed as LDH).

GA was incorporated into LDH layer using the ion exchange methods based on our previous study [20]. The speciﬁc procedure consisted of the ultrasonic dispersion of 250 mg of LDH in 60 mL deionized water and the addition of GA solution to LDH suspension, as well as the stirring and reaction at 40°C, 800 r/min for 8 h in N2 atmosphere. The precipitate was collected through filtration. The unloaded GA was washed with ethanol several times and then freezing-dried for 24 h to produce GA-LDH nanohybrid.

2.4. Preparation of GA-LDH/LS Nanocomposites

2.4.1. Thin Film Dispersion Method. In accordance with Gou’s description [21], lecithin and cholesterol were dissolved in 15 mL dichloromethane at a mass ratio of 3:1, and the dichloromethane was evaporated in vacuum in a
55°C water bath until a dry film formed. At the drug/lipid mass ratio 1:5, GA-LDH was dispersed in 30 mL water and ultrasonically dispersed to form a uniform suspension. 5 mL chloroform was added to well dissolve the lipid film, dropping GA-LDH suspension into the film solution, continued evaporating dichloromethane under reduced pressure, and fully hydrated for 2 h. The resulted suspension was dispersed using cell pulverizer (SCIENTZ-950E, Ningbo Xinzi Biotechnology Co., Ltd., China) to homogenize the nanocomposites and then freeze-dried using freeze dryer (Beijing Boyikang Experimental Instrument Co., Ltd., China) to produce the GA-LDH/LS nanocomposites.

2.4.2. Reverse Phase Evaporation Method. The lipid film and GA-LDH suspension were prepared by the same ratio and the same procedures, as illustrated in the “Thin Film Dispersion Method” section. The lipid film was dissolved with 5 mL dichloromethane. GA-LDH suspension was added to the film solution, and the mixed solution was kept stirring and ultrasonically treated for 30 min, respectively.

Dichloromethane was removed through rotary evaporation and fully hydrated for 2 h. The suspension was dispersed by cell pulverizer and then freeze-dried to produce GA-LDH/LS nanocomposites.

2.4.3. Ethanol Injection Method. Lecithin and cholesterol were dissolved in 15 mL ethanol at a mass ratio 3:1. GA-LDH was ultrasonically dispersed in 30 mL distilled water and stirred at 55°C. At a drug/lipid mass ratio 1:5, the ethanol solution of lipid was drawn into a syringe and then slowly injected in the GA-LDH suspension at a speed of 1 mL/min. The resulted suspension was continuously stirred and then evaporated, and the evaporation was stopped in 2 h when the volume of the remaining solution was slightly lower than 30 mL. The GA-LDH/LS nanocomposites were produced by dispersing the suspension by cell pulverizer and then freeze-dried.

2.5. The Determination of Drug Encapsulation Efficiency. A weighed amount of GA-LDH/LS was placed in a 10-mL volumetric flask. Subsequently, two drops of concentrated H₃PO₄ were added dropwise to destroy drug-loaded samples and release the contained drug. Next, methanol was introduced, GA was ultrasonically dissolved, and the volume was set to the mark. It was filtered through 0.45-μm microporous membrane, and 20 μL filtrate was injected into the HPLC. The samples were injected three times and determined the GA concentration to attain the drug encapsulation efficiency (DEE).

\[
\text{DEE} \; (\%) = \left( \frac{\text{mg encapsulated drug/mg initial drug}}{100} \right)
\]

2.6. Drug Release Properties Exhibited by GA-LDH/LS. The kinetic release of GA-LDH/LS in vitro was achieved by dialysis membrane (molecular weight cut-off, 3500 D). A weighed amount of drug-loaded samples was immersed in an appropriate amount of release medium (pH = 7.4 phosphate buffer solution (PBS) contained 20% acetone), transferred into a dialysis bag, and then suspended in a tube of 30 mL release medium. The sample tube and tube of fresh release medium were both placed in a 37°C water bath under slight stirring. At certain time intervals, 2 mL of release medium was taken out and substituted by the same amount of fresh release medium. We measured the released GA concentration with the use of UV-vis spectrophotometer. The drug cumulative release amount was attained according to the following formula, and the drug kinetic release curve was generated.

\[
E = \frac{\sum_{i=1}^{n} C_i + V_0 C_n}{m_0} \times 100\%
\]

where \(E\) is cumulative release amount of GA, %; \(V_e\) is volume of replacement medium, 2 mL; \(V_0\) is volume of release medium, 30 mL; \(C_i\) is GA concentration in the release media during the \(i\)th replacement sample, mg/mL; \(m_0\) is GA mass contained in GA-LDH/LS, mg; and \(n\) is number of replacing medium.

2.7. Hemolysis Test. 20 mL fresh anticoagulated rabbit blood was collected in a beaker and removed fibrinogen under a glass rod stirring. Physiological saline was introduced in blood samples and evenly mixed and then centrifuged at 1500 rpm for 5 min to discard the supernatant. The mentioned procedures were repeated till the supernatant were colorless. The remaining erythrocytes suspensions were diluted into a 2% (v/v) erythrocyte suspension with 0.9% saline for the following test.

Varied amounts of GA-LDH/LS were added to the freshly prepared erythrocytes suspension, and the final suspension concentration were 0.01, 0.02, 0.03, 0.04, and 0.05 mg/mL, respectively. The resulted suspensions were thoroughly mixed and then placed in a 37°C water bath. After 3 h, the mixed suspension was taken out and centrifuged. We measured the supernatant absorbance with UV-vis at 540 nm and obtained the hemolysis degree by the following formula:

\[
\text{Hemolysis percentage(%) = } \left( \frac{\text{Abs}_{100} - \text{Abs}_{0}}{\text{Abs}_{100}} \right) \times 100\%
\]

in which Abs₁₀₀, Abs₀, and Abs denote the absorbance of distilled water group, the absorbance of normal saline group, and the absorbance values of the sample, separately.

3. Results and Discussions

3.1. Preparation Method of GA-LDH/LS Nanocomposites. Multiple preparation methods of drug-LDH hybrids have been reported [23–26]. In this study, GA-LDH was synthesized by ion exchange method, of which DEE was 46.29% when the weight ratio of drug to LDH was 3:5, which was employed for the subsequent experiments. The drug-loaded samples were dissolved using the acid-destroying method, and the GA contained in it was released. A standard curve \(A = 15002c + 1419.3\) (\(R^2 = 0.9995, n = 6\)) was set for measuring GA in GA-LDH and GA-LDH/LS by HPLC, of which the linearity range was 4–240 μg/mL. Figure 2 illustrates the HPLC chromatography of GA.
GA-LDH/LS nanocomposites were prepared by the thin film dispersion method, the reverse phase evaporation, and the ethanol injection method, respectively. As shown in Figure 3, the DEE of GA-LDH/LS prepared by ethanol injection method was the highest, up to 56.28%. In the injection method, ethanol or diethyl ether generally served as the solvents for dissolving the lipids. Considering the strong toxicity of diethyl ether, the ethanol injection method was selected.

Figure 4 presented the particle size diagrams of GA-LDH/LS prepared by different methods before lyophilization. As depicted in Figure 4, the average particle size of GA-LDH/LS nanocomposites prepared by three methods was approximately 110-130 nm. It was therefore indicated that preparation methods might not significantly affect the particle size of nanocomposites. Due to the effect of encapsulation efficiency, the ethanol injection method was employed to produce GA-LDH/LS in the subsequent experiments.

3.2. Characterization of GA-LDH/LS

3.2.1. Infrared Spectrum Analysis. The FTIR spectra of GA, GA-LDH, lecithin, cholesterol, and GA-LDH/LS are depicted in Figures 5(a)–5(e), respectively. The absorption band E1 (3750-3100 cm⁻¹) in Figure 5(e) covered the stretching vibration of the hydroxyl groups (νO-H) of GA-LDH (Figure 5(b), 3453 cm⁻¹) and cholesterol (Figure 5(c), 3396 cm⁻¹), and it contained the stretching vibrations of amino group in lecithin (Figure 5(d), 3382 cm⁻¹). To be specific, the intense broad band around 3453 cm⁻¹ in the spectra of GA-LDH (Figure 5(b)) belonged to the stretching vibration of O-H in the LDH layer and water molecules between LDH interlayer. The absorption band E2 (2924 cm⁻¹ and 2849 cm⁻¹) belonged to vibration frequency absorption of methyl (νCH₃) and methylene (νCH₂) from GA (Figures 5(a) and 5(b), 2927 cm⁻¹) and the methenyl vibration (νC=H) of the long saturated fat chain of the lecithin (Figure 5(d), 2925 cm⁻¹ and 2853 cm⁻¹). The absorption band E3 (1741 cm⁻¹) belonged to the combined absorption of carbonyl vibration (νC=O) in the GA (Figures 5(a) and 5(b), 1748 cm⁻¹) and lecithin (Figure 5(d), 1737 cm⁻¹). The
absorption band E4 (1685-1538 cm⁻¹) belonged to a total absorption constituted with the similar vibration frequency, which consisted of unsaturated hydrocarbon vibration ν\(_{\text{C}=\text{CH}}\) (Figure 5(d), 1673 cm⁻¹) of the cholesterol, ν\(_{\text{O-H}}\) bending vibration (Figure 5(b), 1635 cm⁻¹) of water molecule between LDH interlayers, and the vibration stretching of benzene ring skeleton on the GA (Figures 5(a) and 5(b), 1633 cm⁻¹, 1595 cm⁻¹). The absorption band E5 (700-400 cm⁻¹) primarily covered the stretching vibration ν\(_{\text{M-O-M, MO}}\) (Figure 5(b), 448 cm⁻¹, M = Mg, Al) of lattice oxygen in GA-LDH.

GA-LDH was employed as a key skeleton of liposome, and its characteristic absorption is presented in Figure 5(e), thus confirming GA-LDH as the main crystal phase in GA-LDH/LS. Lecithin was found as the key raw material to form GA-LDH/LS, and its characteristic absorption peak belonged to the stretching vibration of the ester carbonyl bond ν\(_{\text{C}=\text{O}}\) (Figure 5(d), 1737 cm⁻¹) in the 1741 cm⁻¹ position of GA-LDH/LS; the scissor vibration δ(CH\(_{2}\)) (Figure 5(d), 1467 cm⁻¹) on the hydrophobic chain was found at the 1466 cm⁻¹ position of GA-LDH/LS. The
phospholipid bond $\nu_{P=O}$ (Figure 5(d), 1236 cm$^{-1}$), the stretching vibrations of phosphorus-oxygen bond $\nu_{P-O-C}$ (Figure 5(d), 1067 cm$^{-1}$), and the vibration of carbon-oxygen bond ($\nu_{C-OH}$) of the hydroxyl group in cholesterol were combined with absorption of all components of liposome. It was therefore revealed that GA-LDH/LS were successfully prepared by FTIR analysis.

3.2.2. Powder X-Ray Diffraction Analysis. The structures of bare MgAl-C1-LDH, GA-LDH, and GA-LDH/LS were investigated by XRD patterns and presented in Figure 6. The bare LDH had the characteristic peaks of hydrotalcite-like (Joint Committee on Powder Diffraction Standards (JCPDS) No. 14-0191) at 11.34, 22.84, 34.74, 39.13, 46.36, 60.58, and 61.89 for (003), (006), (012), (015), (018), (110), and (113) peaks, separately (Figure 6(a)). The d-spacing of bare LDH determined from the (003) peak was 7.80 Å, similar to that of Cl$^-$/intercalated LDH reported in previous research [26]. After GA incorporation into LDH, the XRD pattern was found (Figure 6(b)). The d-spacing of GA-LDH, 7.80 Å, was the same with that of bare LDH, thus suggesting that intercalation of GA moieties into the interlayer space of LDH did not occur. A change in crystallinity before and after GA incorporation was found though no significant change was reported in the crystalline phase. The crystallinity along the c-axis and ab-plane directions were determined based on Scherrer’s equation, whose mathematical expression is presented below: $t = 0.9 \lambda/B\cos \theta$; $t$: crystallite size (Å); $\lambda$: X-ray wavelength; $B$: full-width at half-maximum of peak; $\theta$: Bragg angle. The crystallite size along (003) decreased from 13.5 nm to 11.3 after the incorporation of drug; the crystallite size along (110) was fairly analogous before and after the incorporation of GA, showing 28.8 and 27.9 nm, respectively. Similar results of crystallinity reduction along the c-axis were obtained previously when *Glycine max*-Merrell extracts were adsorbed just in the LDH [26]. Furthermore, typical (003) and (006) diffractions were presented in XRD pattern of GA-LDH/LS, consistent with that of bare LDH (Figure 6(a)), thus suggesting the surface modification by liposome did not affect the crystallinity of LDH phase. Notably, there was strong diffraction of organic amorphous crystal phase around 18.9°~23.8°. The changes of the above diffraction peaks could well characterize the structures of LDH (Figure 6(a)), GA-LDH (Figure 6(b)), and GA-LDH/LS (Figure 6(c)).

3.2.4. TEM Morphology. Figure 8 presented TEM observation of LDH particles and GA-LDH/LS nanocomposites. LDH exhibited hexagonal platelet-like morphology with a size of 80 to 120 nm (Figure 8(a)). The particle size of GA-LDH/LS increased obviously, observed in Figure 8(b), whose appearance was nearly spherical, thus revealing the formation of GA-LDH/LS nanocomposite by self-assembly process. Furthermore, lipid bilayers around the GA-LDH nanohybrids could be discerned, as depicted in Figure 8(b), which showed the feature of core-shell structure for the GA-LDH/LS nanocomposites.

3.3. Drug Release Behavior. GA releasing behavior from the drug-loaded samples was investigated in the PBS medium supplemented by 20% acetone. Figure 9 presented the plots of releasing amount of GA vs. releasing time. GA solution reached its equilibrium in 12 h, which was earlier released than GA-LDH and GA-LDH/LS. The release amount of the GA solution reached 53.2% of the total drug amount at 3 h, and almost the total drug amount was released at 12 h. The release of GA-LDH and GA-LDH/LS with equivalence drugs was lower than that of the GA solution, thus revealing a strong electrostatic interaction between LDH layers and GA molecules. The release amount of GA-LDH was 24.5% at 4 h, and that of GA-LDH/LS was 10.6%. The release rate of GA-LDH/LS was more slowly than GA-LDH, which was attributed to the additional control of liposomes. At 48 h, the release amount of GA-LDH/LS reached 29.91%, and that of GA-LDH was 70.36%. Notably, the release process of GA-LDH/LS was more intricate than that of GA-LDH. The released drugs of GA-LDH/LS originated from the dissociative GA filled between the phospholipid bilayer and GA-LDH, inside GA between the interlayers of LDH, and the joint limit of the phospholipid bilayer of liposomes and core skeleton LDH adjusted their release. Moreover, with the extension of the time, the prolonged release characteristic of GA-LDH/LS would be shown gradually, which was primarily attributed to the control action of the liposome [22]. It was proven that the prolonged release profile.
resulting from GA-LDH/LS could lead to a more efficient delivery and benefit of therapeutic cure.

Four different kinetics models (Ritger-Peppas model, Higuchi equation, zero-order, and first-order) have been employed to facilitate the quantitative interpretation of the above results and inquiring into the GA release mechanisms to cognize more about the kinetic release of the GA from GA-LDH/LS. Table 1 listed the linear correlation coefficient ($R^2$) values, which was obtained from the linear fitting. Among the present models, zero-order kinetics showed poor

$R^2$ values and were not capable of explicating the release mechanism. Oppositely, it would be more appropriate to explain the release process of GA from GA-LDH/LS based on the first-order kinetics. It was therefore inferred that the release mechanism of GA-LDH/LS could be a passive diffusion process.

3.4. Hemolysis Test. Figure 10 presented a histogram of the degree of hemolysis of GA-LDH and GA-LDH/LS under different concentrations. The hemolysis percentage of unmodified GA-LDH was higher over the whole concentration. In contrast, the hemolysis percentage of GA-LDH modified by liposome decreased significantly with the same concentration of GA-LDH, of which the hemolysis percentage was lower than 3% over the concentration from 0.01 to 0.05 mg/mL, thus suggesting that liposomes modification could enhance the biocompatibility of LDH. The above result was attained because the positive charge of GA-LDH

**Table 1: Equation fitting of the drug release in vitro.**

<table>
<thead>
<tr>
<th>Model</th>
<th>Equation</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero-order kinetics</td>
<td>$M_t = 0.00545t + 0.02905$</td>
<td>0.64835</td>
</tr>
<tr>
<td>First-order kinetics</td>
<td>$M_t = 0.303(1 - e^{-0.104t})$</td>
<td>0.99162</td>
</tr>
<tr>
<td>Higuchi equation</td>
<td>$M_t = 0.04933 t^{1/2} - 0.00756$</td>
<td>0.8558</td>
</tr>
<tr>
<td>Ritger-Peppas</td>
<td>$M_t = 0.0622 t^{0.436}$</td>
<td>0.8722</td>
</tr>
</tbody>
</table>
was further reduced by liposome modification. As a result, the damage to erythrocytes of GA-LDH/LS was significantly reduced.

4. Conclusions

In this study, GA was incorporated in the LDH layers depending on an electrostatic interaction between negatively charged GA and positively charged LDHs, denoted as GA-LDH. GA-LDH was further modified by liposome by ethanol injection method. The DEE was 56.28%. The XRD, FTIR, and TEM analysis confirmed that the structure of GA-LDH would not be destroyed by liposome modification. The GA release of GA-LDH/LS in PBS indicated that it showed excellent sustained and controlled drug release, with 29.91% delivery time of 2 days, without “burst” release, superior to the GA-loaded PEGylated liposomes [9]. Furthermore, and the hemolysis percentage of GA-LDH modified by liposomes decreased significantly. Thus far, this study has been the first report on LDH-based GA delivery vehicles. The results of the incorporation and delivery of the GA suggested that this study provided a safe and effective drug delivery carrier of the anticancer drug. Study on the antitumor activity in vitro of GA-LDH/LS nanocomposites will be investigated in the next step work.

Data Availability

Data are available on request.

Conflicts of Interest

The authors declare no conflict of interest.

References


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