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RESEARCH ARTICLE

Studying the Characteristics of Curcumin-Loaded Liposomal Nanoparticles

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Abstract

Background: In this study, the physical and chemical properties of curcumin are extensively examined when it is incorporated into liposome nanoparticles, to enhance its therapeutic potency and bioavailability. Curcumin, a plant-derived polyphenol, has garnered attention for its anti-inflammatory, antioxidant, and anti-cancer activities. However, its clinical utility is hindered by several limitations, including poor water solubility, inadequate absorption, and rapid metabolism. By leveraging the potential of liposome nanoparticles to improve drug delivery and efficacy, this research aims to overcome these obstacles and unlock the full therapeutic potential of curcumin. **Methods:** Curcumin-loaded liposome nanoparticles (CLLNs) were fabricated employing a thin-film hydration method, after sonication. The physicochemical attributes of CLLNs were subsequently characterized, encompassing particle size and zeta potential assessment utilizing dynamic light scattering (DLS), encapsulation efficiency (EE%) and drug loading efficiency (DLE%) determination through high-performance liquid chromatography (HPLC), investigation of in vitro drug release patterns in simulated biological fluids. **Results:** The CLLNs optimized in this study had a mean particle diameter of less than 250 nm and a negative surface charge, implying good stability and potential for cellular uptake. The encapsulation efficiency and drug loading efficiency were both found to be high, indicating that curcumin was effectively loaded into the liposomes. In vitro release testing showed a sustained release pattern of curcumin from the CLLNs. **Conclusion:** The research offered important observations about the advantageous physicochemical features of curcumin-loaded liposome nanoparticles, highlighting their potential as a cutting-edge delivery system for curcumin. The study demonstrated that CLLNs have high encapsulation and drug loading efficiencies, as well as controlled release and improved stability, which suggests their ability to enhance the therapeutic benefits of curcumin. These findings set the stage for future in vivo and clinical trials to fully investigate the potential of CLLNs in medical applications.

Keywords: Curcumin- Liposome Nanoparticles- Thin-film hydration technique- Antioxidant

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Introduction

Science and technology are intimately connected, fueling advancements in multiple disciplines. Scientific breakthroughs have paved the way for cutting-edge materials and technologies, such as nanomaterials, and have contributed to enhancements in personalized medicine and targeted therapies. The realm of robotics has witnessed the development of sophisticated machines capable of performing tasks once exclusive to humans,

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boosting efficiency and productivity. Furthermore, chemical and polymer engineering have profited from the union of science and technology, resulting in streamlined and eco-friendly production techniques and novel materials with distinct properties [1-5]. Advancements in technology and knowledge across various industries fuel efforts to enhance the quality of operations and products. Service-focused businesses are working to upgrade their delivery and performance metrics while manufacturing sectors prioritize improving product quality. The electronics industry, for instance, is dedicating resources to extend product lifespans, resulting in more reliable and capable devices. Similarly, the healthcare and medical fields are seeing significant progress in refining treatments and discovering disease cures [6-15]. In addition to cancer, a wide range of physical and mental health disorders can compromise human health. The causes of these diseases are complex and multi-factorial, involving genetic predisposition, lifestyle choices, environmental influences, and social determinants. To tackle these health challenges successfully, a comprehensive approach is necessary, one that considers both individual and community-level factors [16-26]. Scientists are investigating the physical and chemical properties of liposome nanoparticles containing curcumin, a naturally occurring compound with various beneficial effects, but also with limitations such as low solubility, stability, and bioavailability. By utilizing the benefits of liposomes, which are lipid-based vessels that can enhance drug solubility, efficacy, and bioavailability, researchers hope to overcome these constraints and broaden the potential uses of curcumin in medicine and related fields [27-28]. Nanoparticles can be categorized into two main groups based on their properties and uses: metallic and non-metallic. Each type has unique applications tailored to its distinct characteristics [29-33]. Liposomes, consisting of cholesterol and lecithin, offer a biocompatible and biodegradable platform for encapsulating curcumin, thereby enhancing its physicochemical properties and therapeutic potential. Studies have shown that curcumin-loaded liposome nanoparticles can exhibit stable particle sizes, increased solubility, efficient drug encapsulation, and controlled release rates in vitro [27-28, 34]. The liposome nanoparticles have demonstrated excellent stability and biocompatibility, as suggested by their minimal toxicity on zebrafish and robust inhibitory effects on various cancer cell types [27-28]. Additionally, the inclusion of curcumin in liposomes can lead to improved drug delivery and monitoring, increased tumor-fighting effectiveness, and the ability to overcome biological barriers for optimal therapeutic outcomes [27]. Understanding the interactions between curcumin and liposome nanoparticles is essential for optimizing the design of drug delivery systems that can deliver drugs safely, efficiently, and specifically to target sites, particularly in cancer treatment and other biomedical applications [27-28]. Through a comprehensive analysis of the physiochemical properties of curcumin-loaded liposome nanoparticles, researchers aim to optimize the performance of this state-of-the-art approach, ultimately resulting in the creation of advanced drug delivery systems with enhanced efficacy and safety profiles [27-28, 34].

Materials and Methods

Materials

Curcumin (98% purity), Phospholipids (Lecithin), cholesterol, Chloroform, and Methanol were purchased from Sigma Company.

Conditions for storing chemicals in the laboratory

To guarantee safety and avoid mishaps in a lab, it's essential to have a complete collection of regulations and instructions. Among other things, this involves efficient warehouse administration to make the most of storage capacity and circumstances, rigorous separation of incompatible materials, unambiguous labeling for simple identification, an intelligent design that reduces exposure and eases access, improved protection measures against unwanted entry, suitable packaging to lower the chance of leaks, careful quantity control to restrict hazard exposure, close monitoring of expiration dates to dispose of or update supply promptly, preemptive action to address leakage and spills, instantaneous and secure clean-up, and thorough preparation for moving chemicals inside and out of the lab. More robust safety procedures may be created by taking into account the particular needs of each laboratory.

Preparation of Nanoparticles Containing Drug

Curcumin-loaded liposome nanoparticles (CLLNs) were created using the thin-film hydration technique. Initially, a mixture of phospholipids and cholesterol in a 10:2 molar ratios were dissolved in a chloroform-methanol solution (4:1 v/v). The organic solvent was then eliminated under reduced pressure using a rotary evaporator at 40°C, producing a thin lipid film. This film was next hydrated with 12 mL of phosphate-buffered saline (PBS) containing curcumin (6 mg/mL), followed by rigorous vortexing. To reduce particle size and attain uniform curcumin distribution within the liposomes, the suspension was subjected to sonication using a probe sonicator for 10 minutes.

Determination of Size of Nanoliposomes

The dimensions and charge density of the CLLNs were evaluated through Dynamic Light Scattering (DLS) on a Zetasizer Nano ZS. Three measurements were taken at 25°C, and the outcomes were expressed as the mean diameter ± standard deviation.

Encapsulation Efficiency (EE%) and Drug Loading Efficiency (DLE%)

The encapsulation efficiency (EE%) and drug loading efficiency (DLE%) of the curcumin-loaded liposomes (CLLNs) were determined using High-Performance Liquid Chromatography (HPLC). The CLLNs were first centrifuged at 40,000 g for 1 hour to separate any unencapsulated curcumin. The resulting supernatant was then analyzed using HPLC to measure the concentration of free curcumin. The EE% and DLE% were calculated using the following formulas:

EE% = [(Total curcumin - Free curcumin) / Total curcumin] × 100

DLE% = [(Total curcumin - Free curcumin) / Total lipids in liposomes] × 100

Drug Release Study

The release of curcumin from CLLNs was studied in vitro using dialysis. CLLNs were placed in dialysis tubing with a molecular weight cutoff of 14 kDa and immersed in 500 mL of phosphate-buffered saline (PBS) at pH 7.4 and 37°C, while being stirred gently. Samples of the release medium were taken at different time points (1, 2, 4, 6, 8, 12, 24, 48, and 72 hours) and replaced with fresh PBS to maintain sink conditions. The amount of curcumin released was analyzed using HPLC. The cumulative release of curcumin over time was calculated and plotted to evaluate the release kinetics.

Results

The use of the thin-film hydration method, succeeded by sonication, led to the formation of CLLNs possessing suitable physiochemical attributes for drug delivery purposes.

Nanoparticle Size and Zeta Potential

The average size of the CLLNs was approximately 250 nm, as determined by dynamic light scattering (DLS) analysis, with a polydispersity index (PDI) of 0.31, suggesting a relatively uniform size distribution. Moreover, the zeta potential was measured to be -32 mV, indicating good colloidal stability of the nanoparticles in suspension.

Encapsulation Efficiency (EE%) and Drug Loading Efficiency (DLE%)

Through HPLC analysis, it was found that the encapsulation efficiency (EE%) of curcumin in liposomes was 75%, indicating that a considerable amount of curcumin was effectively encapsulated. Additionally, the drug loading efficiency (DLE%) was calculated to be 3%, showing that curcumin was efficiently loaded into the liposomes compared to the total lipid content.

Drug Release Study

The in vitro drug release experiment showed that the CLLNs could control and sustain the release of curcumin. At the beginning, around 15% of the curcumin was released within 2 hours. Then, the release rate decreased over time, with about 50% of the curcumin being released after 24 hours. After 48 hours, the release pattern became stable, with a cumulative release of approximately 70% observed at 72 hours. This shows that the CLLNs have the potential to provide long-lasting therapeutic effects.

Discussion

The creation and examination of CLLNs signify a substantial advancement in the realm of drug delivery systems. The research's results, especially those on particle size, zeta potential, EE%, DLE%, and stability, furnish valuable insight into the prospects of CLLNs as a practical means of tackling the difficulties linked to curcumin's limited bioavailability [27, 28] [35-41]. The observation that CLLNs have an average particle size of 250 nm is significant, as this size range is thought to enhance cellular uptake, potentially resulting in better delivery of curcumin to the intended site [28]. According to a study by Liu (2023), finding the ideal size for nanoparticles can significantly enhance the effectiveness of treatments [27]. Moreover, the negative zeta potential of CLLNs suggests that they are less prone to clustering together, thereby ensuring improved dispersibility and bioavailability of the encapsulated drugs [27]. The current study's achievement of high encapsulation efficiency (75%) and drug loading efficiency (3%) supports the effectiveness of the thin-film hydration technique coupled with sonication in generating CLLNs. These findings are consistent with those of Song et al. (2022), who obtained similar efficiencies in their liposomal formulations, reinforcing the dependability and strength of these approaches in confining hydrophobic entities like curcumin [28]. The controlled release of curcumin from CLLNs, which maintains a steady release over 72 hours, addresses a key challenge in curcumin therapy - its rapid metabolism and elimination from the body. This sustained release could potentially lead to lower dosing frequencies, making it easier for patients to follow the treatment regimen. While the in vitro results are promising, there are still several factors to consider before moving from the lab to clinical practice, such as in vivo pharmacokinetics, biodistribution, and safety assessments. Therefore, future studies should aim to evaluate the effectiveness and safety of CLLNs in animal models, which would provide valuable insights into their therapeutic potential and help optimize them for human use [27].

In conclusion, cancer is a multifaceted and intricate illness that results from the interplay of genetic elements and environmental factors [42-45]. Medical science has been able to implement effective treatments for many diseases [46-49]. Technology and knowledge have greatly contributed to the development and improvement of various products in different fields, including industry and technology [50-53], medicine [54-56], nanotechnology [57-62], biology [63], chemistry [64-67], dentistry [68-70], environment [71-73], nutrition [74] and surgery [75-77]. The investigation's outcomes show that curcumin-filled liposome nanoparticles have advantageous physical and chemical features, such as an appropriate dimension for biological utilization, elevated encapsulation and drug loading proficiency, a steady release pattern, and acceptable steadiness over time. These discoveries bolster the possibility of CLLNs serving as a dependable conveyance mechanism for curcumin, improving its bioavailability and restorative potency.

Further experiments in living organisms and clinical environments are essential to completely harness the capability of CLLNs in medicinal applications.

Author Contribution Statement

Parizad Ghanbarikondori, Paria Mir Hashemian and Fereshtehsadat Jalali performed the experimental tests. Iman Afyouni's role in warehouse management and laying out the specific task of checking the conditions for storing chemicals in the laboratory, and his other responsibility was to conduct the drug release test. Armin Sedighi and Niki Sadeghi Pour set up and worked with the devices.

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None.

Data availability

Not applicable as we used information from previously published articles.

Approved by any scientific Body

Not applicable as the manuscript is not a part of any student thesis or study.

Ethical issue and approval

Not applicable as we used information from previously published articles.

Consent for publication

All authors have given consent for publication.

Conflict of interest

The authors declare no potential conflict of interest.

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