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A REVIEW ON NANOSPONGES

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Abstract

The development of targeted drug delivery systems has faced challenges due to the complex chemical reactions involved. However, nano-sponges, a newly developed colloidal system, show promise in overcoming issues such as drug toxicity, poor bioavailability, and inconsistent drug release. These nano-sponges are small, porous structures that can be tailored to carry both hydrophilic and hydrophobic drugs. They are easily prepared by crosslinking cyclodextrins with various compounds, benefiting from cyclodextrin's excellent biocompatibility, stability, and safety. Nano-sponges have a wide range of applications, including in the treatment of cancer, autoimmune diseases, and improving drug stability and bioavailability. They offer controlled and predictable drug release by adhering to target sites in the body, preventing drugs from circulating throughout. Additionally, they can be used for oral, topical, and parenteral drug delivery, as well as for delivering enzymes, proteins, vaccines, and antibodies. Nano-sponges are especially valuable for drugs with poor solubility, as their aqueous solubility enhances drug effectiveness. The preparation, characterization, and potential applications of nano-sponges have been extensively explored. These systems can be formulated to deliver drugs in a controlled fashion, addressing challenges such as drug degradation and poor site specificity. Their ability to carry both lipophilic and hydrophilic drugs makes them a versatile option in drug delivery. This review highlights the development, benefits, and challenges of nano-sponges, focusing on their potential in enhancing drug delivery systems and solving long-standing pharmaceutical issues.

Keywords: *Nano-sponges, Crosslinking, Bioavailability, Solubility, Targeted drug delivery system, controlled drug delivery, colloidal carrier, Emulsion Solvent Diffusion Method.*

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Introduction

Nano-sponge is a modern category of material and is made up of tiny particles with a narrow cavity of few nano-meters. The nano-sponges are a three dimensional scaffold (backbone) or network of polyester that are capable of degrading naturally. These polyesters are mixed with a crosslinker in a solution to form Nano-sponges. Here, the polyester is generally biodegradable, so it breaks down in the body moderately. Once the scaffold of nano-sponges breaks down it releases the drug molecules which are loaded, in a derogatory fashion [1].

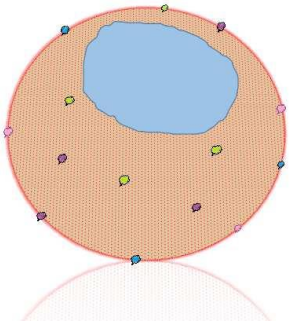

Fig. 01: Structure of a nano-sponge showing a cavity for drug loading

Nano-sponges are tiny mesh-like structures that may revolutionise the treatment of many diseases and early trials suggest this technology is up to five times more effective at delivering drugs for breast cancer than conventional methods. The nano-sponge is about the size of a virus with a 'backbone' (a scaffold structure) of naturally degradable polyester. Which means that when it breaks up in the body, the drug can be released on a known schedule Targeted drug delivery systems have been an undertaking for a long period of time to achieve

the expected outcome? In the start, the drug delivery method of Nanosponge emerged only as a topical delivery system, but in the 21st century, both oral and intravenous (IV) route can be used to administnano sponges [2].

Many of the developments made using nanomedicine:

1. Production of one dose per day of ciprofloxacin
2. Tumor guided taxol delivery
3. Enhanced ophthalmic delivery utilizing wise hydrogel nanoparticles
4. Oral insulin formulation using nanoparticles

Some of the major benefits of this method is reliable release relative to other nanoparticle delivery systems under growth. Controlled release of nanoparticles drug delivery system that can be an enhanced method of delivery for anti-cancer treatments, including direct injection into the sitting tumor [3].

The nanosponges encompass the form of nanoparticles that encapsulate the molecules of drugs within their center. The nanoparticles can be categorized by the process of interaction with drugs into:

1. Encapsulating nanoparticles

Nanosponges and nanocapsules reflect these. Nanosponges involve alginate nanosponges that have several gaps that keep the molecules of the drug. Even encapsulating nanoparticles are nanocapsules such as poly (isobutyl-cyanoacrylate) (IBCA). Within their aqueous base,theycan capture drug molecules.

2. Complexing Nanoparticles

Such nanoparticles bind electrostatic charges to the molecule.

3. Cojugating Nanoparticles

Such nanoparticles are connected by a tight covalent bond with drug molecules [4].

Nanosponges are a unique class of nanoparticles that are generally derived from natural derivatives. Nanosponges are still being used for all these properties in various fields of use, including the cosmetic and pharmaceutical sectors [5]. Nanotechnology has received a lot of attention recently as a result of the discovery of new chemical entities, as well as its use in diagnosis and treatment of a variety of ailments [6].

Materials Used in Nanosponge Preparation

Numerous substances have produced promising results and can be utilized to produce Nanosponges, depending on the desired type of Nanosponges and the required degree of crosslinking.

Polymers and copolymers

The development and performance of nanosponges are affected by the type of polymer utilized for their formulation. In the case of complexation, the cavity of developed nanosponges should be such that it can accommodate a particular drug.

Polymer also depends on the type of drug to be entrapped and the desired release profile the Some polymers used are Cyclodextrin and its derivatives,hypercrosslinked polystyrenes, Eudragit RS100, acrylic polymers, etc [7].

Hafiz et al. formulated a hydrogel of Carboplatin using nanosponges as a carrier. The nanosponges were formulated using etc

Evaluation parameters

Particle Size Determination

Particle size can be determined using laser light diffractometry or a Zeta sizer. Plotting cumulative percentage drug release from nanosponges of different molecule sizes against time can be used to investigate the effect of particle size on drug release.

Loading Efficiency

The loading efficiency of nanosponge can be calculated by subtracting unentrapped drug fromthe total amount of drug. A suitable method of analysis can be used to estimate the amount of untrapped drug. Dialysis, gel filtration, and ultra centrifugation are some of the techniques used to isolate unentrapped drugs. The loading efficiency is measured as follows:

Zeta Potential

Zeta sizer is used to determine the surface charge of nanosponge.

SEM and TEM

Used for morphological characterization and to determine shape of particles.

Fourier transforms infrared spectroscopy (FTIR)

The presence of functional group can be determined using this too.

Solubility Studies

Higuchi and Connors model has described the phase solubility method used to study inclusion complexation, in which effect of a nanospongecan be examined, on the drug solubility. Degree complexation is indicated by phase solubility.

In Vitro Release Studies

A dissolution apparatus USP xxiii with a modified basket made of 5m stainless steel rotating at 150 rpm can be used to determine drug release from nanosponge. The dissolution medium is chosen after considering the solubility of the actives to ensure sink condition. A sample from the dissolution medium may be analysed using a suitable analytical process. In most cases Franz diffusion cell can also be used depending upon the formulation [8].

Characterization of Nanoparticles

Inclusion complexes formed between the drug and nanosponges can be characterized by following methods.

Thermo-analytical methods

Thermo-analytical methods determine whether the drug substance undergoes some change before the thermal degradation of the nanosponge.

Microscopy studies

Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) can be used to study the microscopic aspects of the drug, nanosponges and the product (drug/nanosponge complex). The difference in crystallization state of the raw materials and the product seen under electron microscope indicates the formation of the inclusion complexes [9].

X-ray diffractiometry and single crystal X-ray structure analysis

Powder X-ray diffractiometry can be used to detect inclusion complexation in the solid state. The complex formation leads to the sharpening of the existing peaks, appearance of a few new peaks and shifting of certain peaks Single crystal X-ray structure analysis may be used to determine the detailed inclusion structure and mode of interaction. The interaction between the host and guest molecules can be identified and the precise geometrical relationship can be established [10].

- Structure of drug molecule should not consist of more than 5 condensed rings.
- The solubility of the drug in water should be<10 mg/ml.
- The melting point of the drug should be <250 ° C. Temperature

Changes in the temperature can affect the complexation of drug or nanosponges. Increasing the temperature generally decreases the extent of the stability constant of the drug or the nanosponge complex which may be due to the reduction of interaction forces such as hydrophobic forces and Van der Waal forces of drug/nanosponges with an increase in the temperature changes can affect Drug/Nanosponge complexation [11].

Degree of Substitution

The number, position, and type of the substituent of the parent molecule can affect the ability of complexation of the nanosponges to a greater extent the complexation ability of the nanosponge may be greatly affected by type, number and position of the substituent on the parent molecule The nanosponge's complexation capacity may be severely affected by the substituent's form, number, and location on the parent molecule [12].

Method of preparation

The method of drug loading into the nanosponges can cause a change in the complexation of drug and the nanosponges. Although, the success of a method mainly depends on the nature or the characteristics of the drug and polymer; in some cases, freeze drying has also been known to affect the drug and nanosponge complexation. The method of loading the drug into the nanosponge can affect Drug/Nanosponge complexation. However, the effectiveness of a method depends on the nature of the drug and polymer, in many cases freeze drying was found to be most effective for drug complexation.

Type of Drug & Medium Used For Interaction

The type of drug that needs to be loaded and the solvents can have an impact on the production of Nanosponges, in addition to the type and nature of the crosslinker and polymer used. To be adequately entrapped in nanocavities, drug molecules must have specific properties. Molecules having a molecular mass from 100 to 400 Da, less than 250 C melting point, with fewer than five condensed rings, and less than 10 mg/ml solubility in water are able to be effectively trapped inside a nanocavity Compounds with a higher melting point tend to lose stability after being loaded into Nanosponges, making it impossible for them to form stable complexes between medicines and Nanosponges [13].

Applications

Due to biocompatibility and adaptability, Nanosponges offer a wide range of potential uses in the realm of nanotechnology. There are numerous applications of Nanosponges

Nanosponges for Drug Delivery

Because of their nanoporous structure, nanosponges can advantageously carry water insoluble drugs (Biopharmaceutical Classification System class-II drugs). These complexes can be used to increase the dissolution rate, solubility and stability of drugs, to mask unpleasant flavors and to convert liquid substances to solids [14].

Oral Delivery

The complex can be dispersed in a matrix of diluents, excipients, lubricants, and anti-caking agents for oral administration in the form of capsules or tablets. Acetyl salicylic acid, anonsteroidal anti-inflammatory drug (NSAID) classified as a BCS class III drug, was used to create nano sponges for use in an oral drug delivery system

Topical Delivery

Nano sponge components can be applied topically in the form of a gel or cream. Resveratrol-loaded nanosponges were believed to increase drug permeation in vitro on porcine skin. Nano sponges' ability to increase solubility at the skin's surface may also is attributed to their ability to enhance visitor molecule uptake by the skin [15].

Nano sponge as Chemical Sensors

In rather sensitive detection of hydrogen nanosponge titania, the nanosponge which are kind of metallic oxides act as a chemical sensor. There is less Nanosponge components can be applied topically in the form of a gel or cream. Resveratrol-loaded nanosponges were believed to increase drug permeation in vitro on porcine skin. Nanosponges' ability to increase solubility at the skin's surface may also is attributed to their ability to enhance visitor molecule uptake by the skin. Hindrance to electron transport because the nanosponge structure has no contact point and it result in higher 3D interconnected nanosponge Titania which is sensitive to H2 gas Improve solubility, stability, and bioavailability Salehi et al. formulated β-cyclodextrin nanosponges of D limonene to overcome the problem of high volatility and poor solubility [16]. The results suggested that β-cyclodextrin nanosponges are a suitable carrier for hydrophobic and sensitive compounds, and Limonene nanosponges can be used as a food additive. Encapsulated Limonene showed higher antibacterial activity compared to free Limonene, and the minimum inhibitory concentration of free Limonene was decreased significantly after encapsulation in β-cyclodextrin nano sponges.

Advantages of Nano Sponges

1. Location-specific delivery of drugs.
2. This system offers a wide variety of items to be processed and common side effects.
3. Increased stability, increased beauty, and increased flexibility in the formulation.
4. Nanosponge systems are anti-irritating,

antimutagenic and anti-allergen

Disadvantages

1. Depends upon only the capacities of loading.
2. Small molecules are involved and not large molecules.
3. There can be occurance of dose dumping.
4. Release may be retarded.
5. Nanosponges have the capacity of encapsulating small molecules, not suitable for larger molecules.

Other Applications of Nano-Sponges

Even at very low concentrations, cyclodextrin-based nanosponges may firmly bind and extract organic molecules from water. The similar idea can be applied to the selective combination of polymer and crosslinker to remove bitter components from grape fruit juice. By using size exclusion chromatography, inorganic electrolytes have been selectively separated using the microporous hyper crosslinked Nanosponges [17].

Conclusion

Nanosponges are effective drug delivery systems that can encapsulate both hydrophilic and lipophilic drugs, enabling controlled and targeted release at the desired site. They can be incorporated into various formulations such as topical preparations (lotions, creams, ointments), as well as oral and parenteral systems. This technology offers several advantages, including targeted drug delivery, reduced side effects, improved stability, formulation flexibility, and better patient compliance. Nanosponges can also be applied in fields beyond drug delivery, such as cosmetics, biomedicine, bioremediation, agrochemistry, and catalysis. With their small particle size and spherical shape, nanosponges are ideal for persistent skin delivery and colon-specific drug release systems, offering enhanced drug stability and effectiveness

Author Contributions

All authors are contributed equally

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Declaration of Competing Interest

The Authors have no Conflicts of Interest to Declare.

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