

Nanosponges : Formulation and Evaluation of Nanosponges

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Abstract: This review aims that the study of to formulate and evaluate nonosponges as a Novel drug delivery systems, exploiting their potential to improve the biological availability of drug with long half lives. Nanosponges, tiny mesh structure with enhanced ability to encapsulate water and lipid soluble drug, have gained significant attention in the field of pharmaceuticals. These spherical colloidal particles possess a hydrophobic core, allowing for the transport of therapeutic molecules with both hydrophilic and hydrophobic properties composed of 3D network with long -chain polyester backbones and cross -linkers, nonosponges can be synthesized through the treatment of cyclodextrins with appropriate cross-linkers. The study will investigate the physicochemical properties, in-vitro release profile and biological efficiency of nonosponges, providing insights into their potential applications in pharmaceutical technology.

Keywords: Nanosponges ,3D Network , Cyclodextrin ,crosslinkers ,biological efficacy

I. INTRODUCTION

Nanosponges are tiny mesh structures that can encapsulate a large number of substances and drug molecules^[1, 2]. They have enhanced ability to dissolve water- and lipid-soluble drugs and also possess spherical colloidal properties^[3]. They increase the biological ability of drugs with long drugs.^[4] Inside the hydrophobic room. In addition, due to the nature of external pepidation branches and nanopion's parents, therapeutic molecules, which are both dopply and hydrophobic, can be transported.^[5] They resemble 3D networks with long-chain polyester backbones present in solution and cross-linkers connecting different parts of the polymer^[6]. It has been shown that treatment of cyclodextrins (cyclic oligosaccharides) with appropriate cross-linkers can result in nanosponges, unique nanostructured materials composed of hyperlinked cyclodextrins^[7].

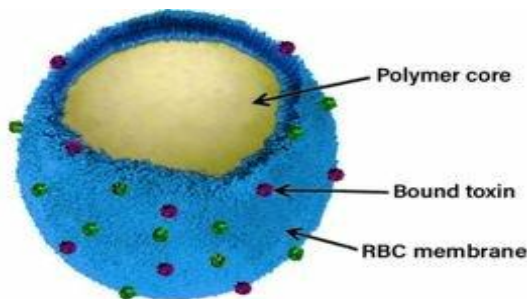


Fig.no 1 : NANOSPONGE

According to the agent used as a cross-linking agent, nanosponges can be synthesized as neutral or acidic materials and swell^[8]. The result is hollow spheres with voids that can hold drug molecules . During preparation, the proportion of cyclodextrin crosslinking can be modified to improve drug loading and provide a customized release profile. Their highly permeable nanomeric nature, compared to that of parent cyclodextrin molecules, allows drug molecules to organize into nanospongy inclusions and interact with each other in a non-inclusion mode and provide efficient drug loading . Compared to other nano particles, they can be easily reproduced using various treatments, so there are several advantages. Wash with environmentally friendly solvent, stripped, relatively harmless heat, gas, delicate heating, or

change Strong. They are used in different areas^[9]. The technical potential of nanosponges stems from the relatively simple principle the chemistry of their cross-linking peptides and polyesters. Being water-soluble, they do not chemically disintegrate in water. Nano humans are composed of several voids in major structures and provide free movement of drug components. Partially Atc he can move freely in the vehicle, reduce the concentration of drugs in the vehicle, create abundant United Nations, and increase the slim balance. This procedure continues until the body has absorbed all of the drug. Once the liquid is prepared, the solubility of the drug molecules increases, reducing the benefit of gradual release and making the drug fragments behave as if they were administered in a free rather than entrapped form^[10]. They mix it with water and use the resulting liquid as a means of transportation. They are a valuable tool for converting liquid materials into solid forms. Nanosponges are able to selectively bind to the target through chemical linkers. They are safe for oral and invasive routes, making them a viable drug delivery vehicle. Nanosponges can be delivered through the lungs, and due to their minute size, veins can be seen^[11]. To produce capsules or tablets for oral administration, the complex can be dispersed in a solution of: a matrix containing diluents, lubricants, adjuvants and anti-caking agents. This step is required for the production process. Non –oral the introduction of substances can be obtained by dissolving sterilized water, physiological solutions, or one of many other aqueous solutions. They can effectively include them in the local hydrogel^[12].

II. CHARACTERISTIC FEATURES OF NANOSPONGES

Nanosponge particles have a certain size, and their polarity can be changed using different ratios of crosslinking agents and polymers. When the polarity of the voids changes, nanosponges can have diameters of less than 1 μm ^[13]. They can be quasi crystalline or crystalline. The crystal structure of nanosponges is important for drug complexation because the level of crystallization significantly affects the stacking performance of nanosponges. Paracrystalline nanosponges have been proven to possess a range of drug loading capabilities according to the literature. They are stable up to temperatures of 130 °C and pHs from 1 to 11. They are porous, biodegradable, and essentially non-toxic^[14]. They can do it for their three -dimensional structure Capsules, transport, and guarantee that drugs and other compounds have been observed. Underwater, nanosponging provides transparency An unclear colloid suspension that can be extracted from extraction of solvent or thermal detachment and extracted from microwave and heat detachment Ultrasound. They show the targeted release of various compounds from the possibility of interaction with several functional Groups that can be improved using synthetic linkers that are aimed at sites. External magnetic field can be used for targeted the category by adding magnetic qualities to the configuration of nanosponges during the production process by expanding ferrite and other Magnetic materials. Nanosponges have been selected as the material of choice for providing sustained release due to their desirable properties: They allow for 24-hour dosing and can be used to encapsulate immiscible liquids, resulting in less irritation and improved flexibility and stability. Although nanosponges have many advantages, they also have some disadvantages. Essentially, small drug molecules are incorporated into the nanosponges, but they can also contain macromolecules and oligonucleotides. The degree of cross-linking affects the ability to load drugs, as it controls the amount of free space within the nanosponge available for loading. Premature degradation of the cross-linker increases the likelihood of dose reset.

III. MATERIALS USED TO MAKE NANOSPONGES

Many substances have shown promising results and can be used to make the desired type of nanosponge. It depends on the material used, the type of nanosponge and the degree of cross-linking required. From his influence on the release of the drug and the encapsulation of the drug, The quantity of sewing is an important component of nanosponges and depends on the concentration of seams. Various components are used, In the preparation of Nanosponge, is discussed below (Table 1). Polymers and copolymers The development and performance of nanosponges is influenced by the type of polymer used in their formulation. In the case of, the cavities of the nanosponges developed must be such that they can accommodate a particular drug for complexation. Choice

Table 1: Materials used within the framework of nanosponges

Sr. No	Ingredients used in nanosponges	Examples
1	Polymers	Cyclodextrin and its derivatives, hypercrosslinked polystyrene, Eudragit RS100, acrylic polymers, etc.
2	Copolymers	Polyvinyl alcohol, polyvalerolactone, allyl valerolactone, ethyl cellulose, etc.
3	Crosslinkers	carboxylic acid dianhydrides, carbonyldiimidazole, dichloromethane, diphenyl carbonate, Glutaraldehyde, etc.

The polymer also depends on the type of drug to be entrapped and the desired release profile^[15]. Some polymers used are cyclodextrin and its derivatives, hypercrosslinked polystyrenes, Eudragit RS100, acrylic polymers, etc.^[16]. prepared ferulic acid nanosponges to improve water solubility. Nanosponges were formulated using cyclodextrin as a polymer. Cyclodextrins are a suitable wall material to trap both hydrophilic and hydrophobic molecules due to their hydrophobic central chamber and hydrophilic surface. Due to the porous structure of the cyclodextrin polymer, the solubility of ferulic acid is enhanced after encapsulation in nanosponges^[17]. Lamy et al. developed Temoporfin loaded nanosponges for neck and head cancer. Nanosponges were prepared using hypercrosslinked β -cyclodextrin polymers. The use of crosslinked β -cyclodextrin polymers improves drug permeation^[18]. Desai et al. Synthetic neuropeptide Y nanosponges cross-linked using β -cyclodextrin. Nanosponges crosslinked with β -cyclodextrin enhance drug release and stability. They are useful for drug administration^[19]. Hafez et al. Carboplatin hydrogel was formulated using nanosponges as a carrier. Nanosponges were formulated using ethyl cellulose using the evaporation method of a double emulsion solvent. Formulated hydrogels containing nanosponge have shown an improvement The effectiveness of the drug in the target zone with prolonged release and biodhesion^[20]. Hao et al. used polylactic acid-glycolic acid-polyethylene glycol copolymer to neutralize tumor acidity and prepared calcium carbonate nanosponges to act as proton nanosponges^[21]. Abemaciclib-loaded nanosponges prepared by Anver et al. using ethyl cellulose and Kolliphor P-188 showed that the amount of ethyl cellulose and Kolliphor P-188 used as copolymers influenced the drug entrapment efficiency. The results showed that a higher amount of ethyl cellulose and a lower amount of Coryphore P-188 could increase the encapsulation efficiency and prevent drug leakage from the nanosponges^[22]

Sewing agent (crosslinking agent)

The type of sewing depends on the structure of the polymer and drug that needs to be nanopant. Dian Hidridokarboxylic acid, CarbonylJitomaidazole, Jiflman, Ziphenyl, Glutardogyde, etc. Used sewing agent . The number of crosslinks is the most important component of nanosponges, as it affects the drug release and encapsulation behavior, and depends on the concentration of the crosslinker. (new11) Balancing hydrophilicity and hydrophobicity Nanosponges can be prepared to deliver active drug molecules by varying the concentration of the crosslinker. Depending on the type of crosslinker used, water-soluble or insoluble nanosponge structures can be developed. In addition, different crosslinkers can significantly alter important properties such as the swelling ability and hydrophilicity or hydrophobicity of the polymer^[23] Ansari et al. To improve solubility and stability, resveratrol nanosponges were formulated using cyclodextrin as a polymer and carbonyldiimidazole as a cross-linking agent, which forms an inclusion complex with the drug, increasing its solubility^[24]. Taleb et al. prepared quercitrin-loaded nanosponges using β -cyclodextrin and 2-hydroxypropyl- β -cyclodextrin separately as polymers and diphenyl carbonate as a cross-linking agent. The results of particle size depicted that the amount of crosslinker used affects the particle size of nanosponges. For the two types of used Cyclodextrins, it was shown that formulations with greater molar ratios of crosslinker had Particle size that was larger than those with lower molar ratios of crosslinker^[25]. To improve the binding properties of conventional cyclodextrin nanosponges, Massaro et al. proposed the synthesis of cyclodextrin-calixarene copolymers using triazole as a binding agent. Quercetin and silibinin, two polyphenol bioactive chemicals, have been used to fabricate composite materials using this combination of cyclodextrin-calixarene nanosponge materials^[26].

IV. LITERATURE REVIEW

1] Himanshu bhowmik et al (2018)

Recent advances in nanotechnology have led to the development of targeted drug delivery systems. However, to effectively deliver a molecule to a specific location using a drug delivery system, a specialized drug delivery system is required. The discovery of nanosponges has been a significant step forward in overcoming certain issues such as drug toxicity, poor bioavailability, and drug release in a predictable manner as they can accommodate both hydrophilic and hydrophobic drugs. Nanosponges exhibit an inherently porous structure and have the unique ability to entrap drug molecules and achieve the desired release. Nanosponges are tiny sponges that can travel through the body to reach specific locations, bind to surfaces, and release drugs in a controlled and predictable manner. Nanosponges can be prepared by cross-linking cyclodextrins with carbonyl or dicarboxylate (cross-linking agents). Nanosponge technology has been widely investigated for drug delivery for oral, topical, and parenteral administration. Nanosponges also act as effective carriers for enzymes, proteins, vaccines, and antibodies.

2] Rahul Salunke et al (2019)

Objective: The aim of this study was to develop and characterize optimal stable gliclazide (GLZ) nanosponges using emulsion solvent diffusion method with the aim to enhance its bioavailability and drug release in a sustained and controlled manner. **Methods:** GLZ nanosponges were prepared by emulsion solvent diffusion method using different drug to polymer ratios (1:1 to 1:5). The polymer used is Eudragit S100. The compatibility of GLZ with the polymer was evaluated by differential scanning calorimetry (DSC) and Fourier transform infrared spectroscopy (FTIR). All formulations were evaluated for product yield, entrapment efficiency, in vitro drug release, scanning electron microscopy (SEM), and stability studies. **Results:** DSC and FTIR studies showed no interaction between the drug and polymer. The product yields for all batches ranged from 73.8 ± 0.30 to 85.6 ± 0.32 . The highest yield of products was shown by batch F3, the collection efficiency of batch F3 was 70.6 ± 0.77 . The average particle size is from 303 ± 2.36 to 680 ± 2.50 nm. At the end of 10 h, formulation F3 showed the highest drug release of $94.40 \pm 1.12\%$. The release kinetics of the optimized formulation shows zero-order drug release. Stability studies show that there is no significant change in the in vitro dissolution profile of the optimized formulation

3] Abdul waris khan et al (2021)

Nanotechnology mediated drug delivery has been reported to enhance the drug efficacy, bioavailability, reduced toxicity and improve patient compliance by targeting the cells and tissues to elicit the desired pharmacological action. The main aim of the study was to formulate lovastatin loaded nanosponges and to evaluate them. Lovastatin charged with nanosponges It was prepared by diffusion of emulsion solvent using various polymers (ethylcellulose, polyvinyl alcohol, β -cyclodextrin, page F68, propyl hydroxy β -cyclodextrin). The FTIR test is carried out as a preliminary test, because of this There was no interaction between the drug and the polymers. Next, the Namp Spage was estimated by the particle size and PDI. Zeta is the possibility of SEM, which is the effectiveness of capture and release of Invitro drugs. The particle size has changed from 295.5 to 578.8 nm. The PDI changed from 0.189 to 0.465, and the bunker potential was -35.96 MV from -17.3, and the capture efficiency has changed. 78.38-95.77 %. The cumulative release percentage from all nanosponges varied from 66.86 to 96.60% after 12 h depending on the drug-to-polymer ratio, with the F6 formulation showing the highest drug release percentage (96.60%). Release kinetic studies showed that the release was first-order diffusion controlled, and the n value (0.6017) of the Korsmeyer-Peppas model indicated that the release mechanism was of non-Fickian type

4] Dalia a. gaber et al (2023)

Cyclodextrin nanosponges are solid nanoparticles developed by crosslinking cyclodextrin polymers. They have been widely used as excellent delivery systems for water-insoluble drugs. The aim of this study is to improve the solubility of piroxicam (PXM) using a β -cyclodextrin-based nanosponge formulation. PXM nanosponge (PXM-NS) formulations were prepared using β -cyclodextrin and carbonyldiimidazole as crosslinkers, and three drug/nanosponge ratios as well as three β -cyclodextrin/crosslinker ratios were tested. Piroxicam nanosponge formulations were characterized for particle size, zeta potential, physical compatibility, and in vitro release. To obtain the optimal formulation, stability studies were performed at three temperatures (4°C, 25°C, and 40°C). Finally, the in vivo analgesic activity and pharmacokinetic parameters of the optimal formulation were performed. The optimized formulation of PXM-NS (PXM-NS10) showed particle size (362 ± 14.06 nm), polydispersity index (0.0518), zeta potential (-17 ± 1.05 mV) and

%EE (79.13 ± 4.33). The dissolution study showed a significant increase in the amount of PXM dissolved compared to the unformulated drug. Research on stability has shown that nanospon has been accepted for 90 days at 4 ° C and 25 ° C for 90 days. It has been confirmed that in Vivo's analgesic research has increased in PXM in the mouse's analgesic reaction. 1.42 times with relative bio -availability of PXM -NS10 compared to over -the -counter drugs. Nanosponges prepared under optimal conditions are promising formulations to enhance the solubility and hence bioavailability of piroxicam

5] Akash Garg et al (2024)

Nanosponges The complex chemical reactions related to the production of new drug administration systems have hindered the efforts to create a targeted drug delivery system for a long time. Nano Spunation, a recently created colloid system, can overcome drug toxicity, decrease in biopailability, and release drugs in a wide area. Nanosponges are tiny sponges consisting of a three-dimensional network with porous cavities. They can be easily prepared by cross-linking cyclodextrins with various compounds. Due to the excellent biocompatibility, stability, and safety of cyclodextrin, numerous cyclodextrin-based drug delivery systems have been rapidly developed. Nanosponge-based drug delivery systems have various applications in various diseases, including cancer, autoimmune diseases, therapeutic applications, enhanced bioavailability, and stability. This review details the advantages and disadvantages, preparation methods, factors affecting their preparation, characterization methods, applications and the latest developments in the field of nanosponges.

AIM AND OBJECTIVES:

AIM :

- To review and study nanosponge as a novel and targeted drug delivery system and to formulate and evaluate nonsponges .
- Nanosponges are an innovative drug delivery system that has recently emerged due to the rapid development of nanotechnology and the need for precise and targeted drug delivery systems.
- These are very small, microscopic spongy particles, roughly the same size as a virus, that consist of a series of cavities that can be filled with drugs.

Objectives :

1. To discuss nanosponges.
2. Advantages and disadvantages .
3. Factor influencing their formation.
4. Method of preparation .
5. Characterization.
6. Applications.

PLAN OF WORK:

Literature Review

Collect necessary solvents and reagents, chemicals, materials needed for experimentation

To perform formulation of Nanosponges by various methods .

To evaluate formulated Nanosponges .

Data Analysis .

Documentation.

NOTE : METHODS OF FORMULATION OF NANOSPONGES

Methods of preparation of Nanosponges :

Quasi emulsion solvent diffusion

Ultrasound-assisted synthesis

Solvent method

Hyper crosslinked method

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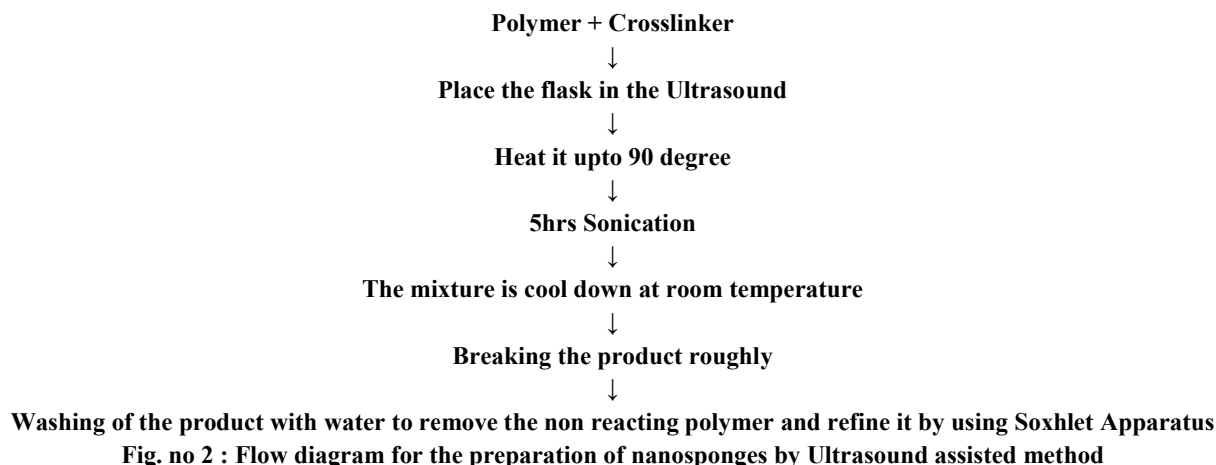
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Microwave irradiation method
Polymerization

1] Ultrasonic-assisted synthesis

The polymers are forced to react with the crosslinking agents in the vial without solvent. The vial is placed in an ultrasonic bath filled with water and heated to 90 ° C, and the mixture is subjected to ultrasonic treatment for 5 hours. The mixture is then cooled to room temperature and the product is coarsely crushed. Finally, the non-reactive product is washed with water to remove the polymer. A Soxhlet (ethanol) apparatus is used to obtain the nanosponges. [27]



2] Emulsion Solvent Diffusion Method

In this method, nanosponges are prepared using different proportions or amounts of ethyl cellulose. And polyvinyl alcohol. This method uses twophases – dispersed and continuous. The dispersed phase consists of ethyl cellulose and the drug, which is dissolved in 20 ml of dichloromethane, and a small amount of polyvinyl alcohol (PVA) is added to 150 ml of the continuous (aqueous) phase. The mixture is then stirred at 1000 rpm for approximately 2 hours. Product, It is assembled by filtering. Finally, the product is dry with Innoanon Temperature 400 ° C [28]

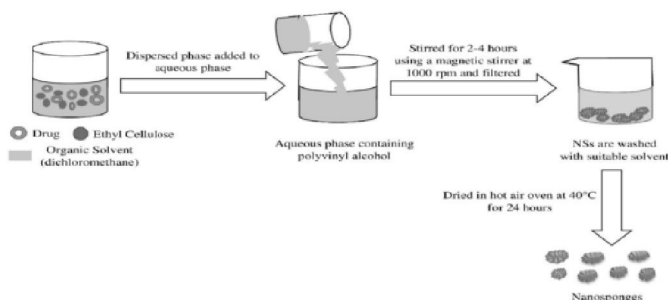


Fig.no.3: Emulsion solvent diffusion method

3] Hypercrosslinking method

Hypercrosslinking method Also known as the fusion method. 100 ml of anhydrous dimethylformamide and 17.42 g of anhydrous cyclodextrin were added to a round-bottom flask, and the mixture was gently stirred until completely dissolved. 9.96 g of carbonyldiimidazole was added to this combination and the reaction was carried out for 4 hours at 100 ° C. Upon completion of the condensation polymerization, highly cross-linked cyclodextrin is formed in the round-bottom flask [Fig.no:4 (D)]. Deionized water should be added in excess to the above mixture to remove excess dimethylformamide. Finally, ethanol-based Soxhlet extraction is used to remove unreacted chemicals [29,30]. Swaminathan et al. β-Cyclodextrin nanosponges were synthesized by crosslinking with 2-methylpiperazine and 2,2-

bisacrylamidoacetic acid or polyamidoamine segments derived from 2,2-bisacrylamidoacetic acid. Both nanosponges based on cyclodextrins showed a protein loading of over 90% with a sustained release profile for bovine serum albumin [31].

4] Microwave method

Microwave method In the CLAT scientific microwave system, a microwave reaction was performed. Optical fabric probe has been introduced in the reaction .

A container that measures the temperature of the reaction mixture. Creation of nanosponges based on cyclodextrin, diphenyl carbonate Diphenylformamide was used as a cross-linking agent It acted as a solvent, i.e. a mixture of cyclodextrin and diphenyl carbonate.

Dimethylformamide was added to a 250 ml flask and heated in a microwave oven under specific conditions for a specific time.

After some time, the solvent was completely removed. The resulting product was then thoroughly purified by Soxhlet extraction with ethanol.

White powder after that, it was generated and dried in a 60 ° C oven until it was ready to use^[32]Singireddy et al. investigated the advantages of microwave-assisted heating over traditional heating methods during the synthesis of cyclodextrin-based nanosponges.

According to the results of the study, the retention capacity of the model drug was increased by half when the nanosponges were produced using microwave assistance.

High-resolution transmission electron microscopy results demonstrated that microwave-synthesized NSs were highly crystalline and had a limited size distribution in addition to a higher degree of complexity.

The advantage of using microwave irradiation for synthesis is that it provides direct energy, allowing for precise delivery of the target molecule.

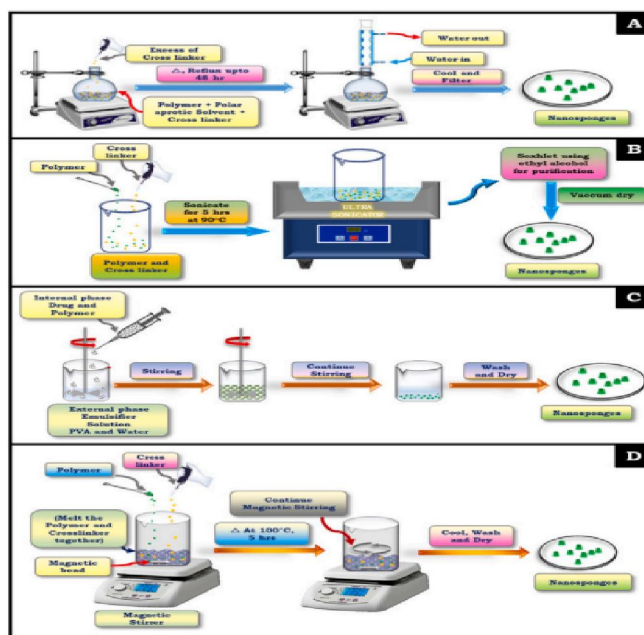


Fig.no:4. Formulation methods of Nanosponges (A) Solvent Method (B) Ultra-Assisted synthesis (C) Emulsion solvent diffusion method (D) Melting method Reprinted from Ref. [23] with permission from Elsevier.

Mechanism of drug release from nanosponges

Since nanosponges have an open structure (they do not have a continuous membrane in the surrounding nanosponges), the active substance is added to the carrier in an encapsulated form. The encapsulated active substance can freely move

from the particles into the carrier until the carrier is saturated and equilibrium is reached. As soon as the product is applied to the skin The ingredients of the actor become immersive and cause violations I have a balance. Therefore, the flow of active substances in nanospongeThe particles in the vehicle start with the epidermis toward the car Absorption or drying. The release of active substances into the skin continues for a long time even after the nanosponge particles are retained on the surface of the skin, i.e. in the stratum corneum. [Nanosponge : A Review by Himangshu Bhowmik]

FACTORS AFFECTING NANOSPONGES

Factors that affect the preparation of nanosponges :

1] Nature of polymer

The polymer used in the preparation of nanosponges can influence its formation and can also affect the pre-formulation. The size of the cavity of a nanosponge should be big enough to entrap a drug molecule of a particular size into it for complexation .

Type of polymer influence the performance and formation of nanosponge(cavity size should be suitable to accomodate a drug molecule).^[33]

2] Drug

To be complex with nanosponges, the drug molecules should have some specific characteristics as mentioned below:

- The molecular weight of the drug molecule should be in range ranging from 100-400 Daltons.
- Structure of drug molecule should not consist of more than 5 condensed ring.
- The solubility of the drug in water should be <10 mg/ml.
- The melting point of the drug should be <250 ° C.

Molecular weight = 100 - 400 Da.

Solubility = (water < 10 mg/ml)

Melting point = 250 Degree

Drug Molecule = less than 5 condensed rings

3] Temperature

Changes in the temperature can affect the complexation of drug ornanosponges. Increasing the temperature generally decreases the extent of the stability constant of the drug or the nanospongecomplex 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 .

Increase in the temperature, decrease in the stability of nanosponge.^[34]

4] 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 .

Complexation ability of nanosponge affected by number and position of substituent of parent molecule.[Nanosponge : A Review by Himangshu Bhowmik]

EVALUATION OF NANOSPONGES

1. Particle Size Determination / Analysis

2. Loading Efficiency

3. Entrapment Efficiency

4. Porosity

5. Zeta Potential

6. Solubility Study

7. Polydispersity index

8. Scanning Electron Microscopy

9. Swelling and Water Uptake

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10. Drug content

1] Particle size analysis

The particle size was determined by dynamic light scattering, using a Malvern system, with vertically polarized light supplied by an argon-ion laser (Cyomics) operated at 40 mW. Experiments were performed at a temperature of $25.0 \pm 0.1^\circ\text{C}$ at a measuring angle of 90° to the incident beam. Laser diffraction technology is based on the principle that particles passing through a laser beam scatter light at angles that are directly related to their size. When particle size decreases, the observed scattering angle increases logarithmically. The observed scattering intensity also depends on the particle size and decreases, to a good approximation, with respect to the particle cross-sectional area. Therefore, large particles scatter light at narrow angles with high intensity, while small particles scatter at wider angles but with low intensity.

2] Loading Efficiency-

Loading efficiency (%) of nanosponge can be determined by ,

$$\text{Loading Efficiency} = \frac{\text{Actual drug content}}{\text{Theoretical drug content}} * 100$$

3] Entrapment Efficiency

Weigh accurate quantity of nanosponge + Suitable solvent in a volumetric flask + Flask was shaken for 1 minute(vortex mixer) + Volume made up upto 10 ml with solvent + Solution was filtered and diluted with the concentration of drug(UV Spectrometer) + Yield of nano particles determined by initial weight of nanosponge.

4] Porosity

Percent porosity is given by equation ,

$$\% \text{ Porosity (E)} = \frac{\text{Bulk volume} - \text{True Volume}}{\text{Bulk Volume}} * 100$$

5] Zeta potential

Zeta potential analysis was performed to evaluate the stability of the nanosponges. Zeta potential is a measure of the influence of electrostatic charge. It is the main force that causes repulsion between neighboring particles. The net results are attraction or repulsion depends on the magnitude of the two forces. The empirical rule describes the relationship between the responses of determining the zeta potential of nanosponges. Zeta potential of any system under investigation is a measure of the surface charge.

6] Solubility Study

The most widely used approach to study inclusion complexation in the phase solubility method described by Higuchi and connors model, which examines the effect of a nanosponge on the solubility of drug.

7] Polydispersity index

In light scattering, the terms polydispersity and % polydispersity are derived from a parameter, the polydispersity index. It is calculated from a cumulant analysis of the intensity autocorrelation function measured by DLS. In the cumulant analysis, a single particle size mode is assumed and a single exponential fit is applied to the autocorrelation function, and the polydispersity describes the width of the assumed Gaussian distribution. The Polydispersity Index is dimensionless and scaled such that values smaller than 0.05 are rarely seen other than with highly mono disperses standards. Values greater than 0.7 indicate that the sample has a very broad size distribution and is probably not suitable for the dynamic light scattering (DLS) technique. Different size distribution algorithms work with data that fall

between these two extremes. Particle size, zeta potential and polydispersity index were determined with the same instrument, the Malvern zeta meter^[35,36].

8] Scanning Electron Microscopy

To evaluate the surface morphology of the nanosponges, the sample was analyzed under a scanning electron microscope after preparing the sample by lightly spraying it onto double-sided adhesive tape adhered to an aluminum plug. The stumps were then coated with platinum. The stump containing the coated sample was placed in a scanning electron microscope. The samples were then scanned randomly and photomicrographs were taken at an accelerating voltage of 20 kV. From the resulting image, the average particle size was determined^[37]

9] Swelling and Water Uptake

Percentage of swelling = $\frac{\text{Marking of the cylinder at a specified time point}}{\text{Initial marking before soaking}} * 100$

Percentage of Water Uptake = $\frac{\text{Mass of the hydrogel after 72 hrs}}{\text{Initial mass of dry polymer}} * 100$

10. Drug Content

An accurately weighed amount of 20 mg of lovastatin nanosponge was added to 20 ml of methanol and placed in a container. The thermoshaker was operated at 100 rpm and 25°C for 45 min followed by vortexing for 10 min. The solution was filtered through a 45 µm membrane filter and the drug was measured spectrophotometrically at λ_{max} 237 nm. Based on a previously prepared standard curve. The medication content of the formulated nanospongs has been calculated on the base of the following equation^[38].

V. FUTURE SCOPE

1. Nanosponge as a chemical sensor:

Nanosponges which are the type of metal oxides act as achemical sensor which is used in highly sesitivity detection of hydrogen using in highly sensitive detection of hydrogen using nanosponge titania

2. Oxgen delivery system:

Characterized by using alpa, beta,and gamma cyclodextrins and this are suspended in water and get saturated with water .A silicon form of a membrane can also be used for oxygen permeation with help of nanosponges .

3. Biomedical application :

Nanosponge can be used for a contaminated water nanosponge have been used for the removal of organic impurities in water

Nanosponge as a carrier

Biocatalyst and release of enzymes , proteins , vacciens and antibiotic

The drawbacks can be removed by using enzymes as a biocatalyst as this operate under high reaction speed , mild condition .

Need of study :

- Protection of drug from degradation.
- Nanosponges are non-irritating and non-toxic.
- Nanosponges enhance aqueous solubility of poorly water-soluble(lipophilic) drugs.
- Nanosponge provides improved elegance, stability and formulation flexibility.
- Nanosponges are stable at higher temperature.
- These drug delivery systems minimize side effect.

- It helps to get rid of the toxic substances from the body.
- Better patient compliance.
- Reduce dosing frequency.
- Nanosponges are suitable with most of the vehicles and ingredients.
- Nanosponges are steady over range of pH 1 to 11.
- Nanosponges are capable of converting liquid substances to solid for masking unpleasant flavour.
- Easy scale up for commercial production.

EXPECTED OUTCOME:

Safety Assessment: Contaminant Detection: Establish a method to detect potential contaminants or degradation products in Nanosponge formulations that could affect safety.

Entrapment Efficiency : Entrapment Efficiency is the % of drug loaded within the polymeric nanosponge compared to actual or theoretical mass used for the nanosponges preparation . It is heavily dependent on the polymer drug combination as well as the method deployed.

3. Mechanism of action : Nanosponges are the 3D network polyester scaffold that are spontaneously decompose . These polyesters are combined with cross linkers agent in the solution to create a nanosponge .When loaded nanosponge's breakdown the drug particles will release .

4. Side effects:

- 1) Nanosponge formulation have potential to incorporate just small molecules not large molecules
- 2) Dose dumping may happen .
- 3) The loading ability of nanosponge rest on degree of crystallization.
- 4) May delay the discharge .

5. Compatibility: Formula Studies: Assess the compatibility of Nanosponges with various excipients and formulations to ensure stability and effectiveness in final pharmaceutical products.

6. Method Development Outcomes: Standard Operating Procedures (SOPs): Creation of detailed SOPs for sample preparation, instrument calibration, and data analysis.

7. Method Validation Outcomes: To validate the method used in preparation and evaluation of nanosponges

VI. CONCLUSION

Nanosponge-based systems feature considerable porosity, simple functionalization procedures, unique topology, environmental friendliness, and cost-effectiveness, and have been shown to be an attractive alternative for targeted drug delivery.

Cyclodextrin-based nanosponges stand out from other nanosponges for their unique qualities, excellent biocompatibility, low toxicity, and ease of surface modification, making them the most commonly tested nanosponges in nanomedicine.

By adjusting the concentration of polymers and other materials and the ratio of crosslinkers, the right size can be achieved, which can improve the solubility of various poorly soluble drugs and prevent their degradation.

Nanosponges have found applications in various areas that cannot be achieved by other nanocarriers, such as targeting, improving stability and solubility, preventing drug photodegradation, increasing formulation flexibility, gas administration, blood purification, etc.

It is important to note that although nanosponges have shown promising results in various areas such as drug delivery, oncology, and COVID-19, further research and development is required to determine their properties, optimize their performance, and ensure their safety.

Ethical considerations, regulatory approvals, and scalability will also play a role in determining the practical applications and widespread adoption of nanosponges in future.

Despite the applications discussed above, nanosponges have various other applications like environmental clean-up (absorption of pollutants and other contaminants) and industrial applications (absorb and recover valuable materials from waste during the manufacturing process)

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