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A REVIEW ON THE PREPARATION AND CHARACTERIZATION OF SODIUM ALGINATES BEADS

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ABSTRACT

Sodium alginate beads are widely used polymeric delivery systems formed through ionic gelation of sodium alginate with multivalent cations, commonly calcium ions. These beads have gained significant attention in pharmaceutical, biomedical, food, and biotechnology applications due to their biocompatibility, biodegradability, non-toxicity, and mild preparation conditions. The gel network produced during cross-linking enables effective encapsulation of drugs, probiotics, enzymes, and bioactive compounds, protecting them from environmental degradation and allowing controlled or sustained release. The physicochemical properties of sodium alginate beads including size, porosity, mechanical strength, and swelling behaviour can be modified by adjusting alginate concentration, crosslinking ion concentration, curing time, and preparation techniques.[1] Such tenability makes them suitable for targeted drug delivery, wound healing formulations, tissue engineering scaffolds, and encapsulation of sensitivebiomolecules. Despite several advantages, limitations such as burst release, low mechanical stability under certain conditions, and sensitivity to pH variations remain challenges that require formulation optimization. Overall, sodium alginate bead technology represents a versatile and cost-effective platform for controlled delivery and encapsulation applications across pharmaceutical and industrial fields.[2]

KEYWORDS: Alginate beads, hydroxyapatite, bone, biodegradable, polymer, bioreactor, mesenchymal stem cells, femoral condyle defect, micro-computed tomography, electro spraying, gelatin, scaffolds and silver nanoparticles.

INTRODUCTION

Metal nanoparticles made from silver, gold, and copper are well-known for their ability to kill bacteria. Silver nanoparticles, in particular, are commonly used as antibacterial agents because they are not toxic and are very effective at killing bacteria. These nanoparticles can be made through a chemical process called reduction, which uses chemicals like sodium borohydride, formamide, and triethanolamine. This method is simple and works well, but it has some downsides. It can be harmful to living things and the environment because of the leftover chemicals used in the process. To avoid this, other methods such as X-ray, UV, and microwave irradiation have been used. These methods help remove the leftover chemicals without the need for extra cleaning steps. Biodegradable material scaffolds help the body repair itself and allow implants to fit better with the surrounding tissue. Using these materials has led to many promising ways to improve how the body heals broken bones and fractures. When choosing materials for this, simple materials with just one component are easier to control and create less confusion when studying how cells interact with them. However, these simple materials don't have the complex structures and compositions that are important for guiding the growth and development of bone tissue, as seen in natural processes or during wound healing.[2]

Recent research has focused on copying parts of the complex structure found in natural tissues. This has shown that including parts of the extracellular matrix in tissue engineering scaffolds is important. These parts help recreate the small-scale structure and active components found in natural bone tissue. In this study, we made silica-alginate nanoparticles using a technique called microemulsion, which is very flexible. We tested how well these nanoparticles could carry and release drugs in response to changes in pH. Alginate, which reacts to changes in pH, was put inside a silica structure that gives the nanoparticles strength. We looked at how different conditions during the making process affected the size and makeup of the nanoparticles. We also checked how the nanoparticles released a model drug, rhodamine B, under different pH levels. This study shows a new way to make composite silica-alginate nanoparticles that could be used as a smart, pH controlled drug delivery system.[3]

Methods of Preparation

Sodium alginate weighing 500 mg was dissolved by heating it in 30 ml of a 2% polymer solution while stirring continuously. Then, 500 mg of metformin was added, and the mixture was left aside for 30 minutes before being placed in a syringe. The solution was then added drop by drop into 100 ml of 2% calcium chloride solution that was being stirred with a magnetic stirrer. The beads formed were filtered. The filtered beads were washed 2 to 4 times with water and then dried.

Ionotropic Gelation Method

First, the best way to make calcium alginate beads was through electro spraying, as shown in the sodium alginate solution was used at concentrations of 0.5%, 1.0%, and 1.5% by weight per volume. The voltage applied during the process was 8, 10, 12, or 15 kilovolts. The sodium alginate solutions were then pushed out drop by drop through a needle attached to a glass syringe, which had a 24-gauge blunt tip with an internal diameter of 0.55 mm. This was done into a solution of 0.5 M calcium chloride while an electric field was applied. The distance between the tip and the collector was kept constant at 15 centimeters. The calcium alginate beads were collected in the calcium chloride solution and gently stirred for 30 minutes. After that, the beads were washed with deionized water and then freeze-dried for 20 hours.[4]

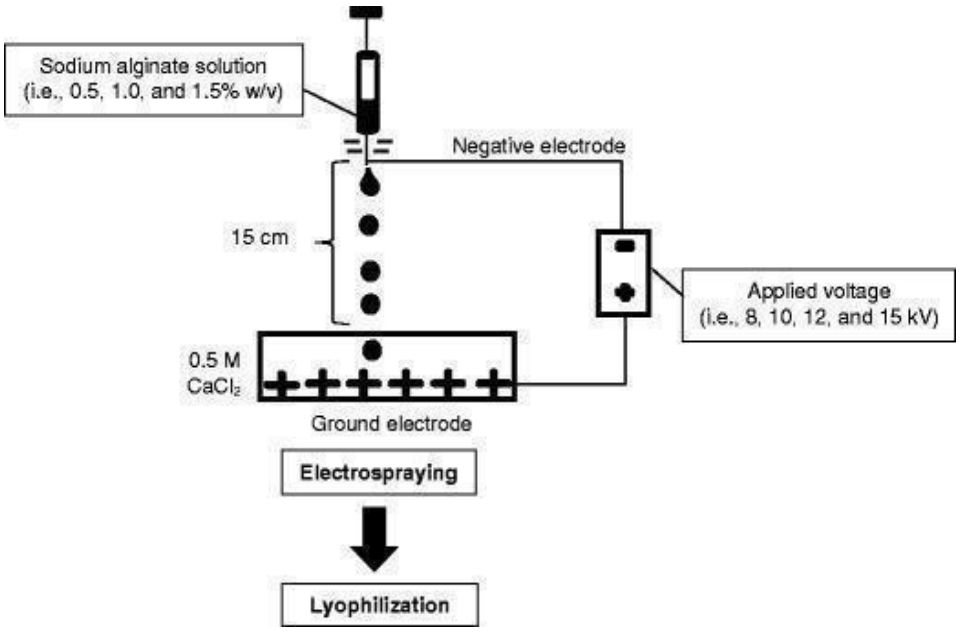

Figure-1.

Emulsion Gelation Method

The calcium alginate beads that trap oil were made using the emulsion gelation method. The

polymer was mixed in water while being stirred at 100 revolutions per minute. Then, 2.5 ml of selected oil was added to the polymer solution. The drug, which was 50 mg, was also added to this mixture. The mixture, which could be either homogenized or not, was gently stirred at 37°C with a temperature variation of 0.5°C at room temperature. This mixture was then pushed through a nozzle into a solution containing 5% calcium chloride. The formed beads were left to sit in the solution for 5 minutes, then they were poured out, filtered, and finally dried for the whole night at room temperature.[5]

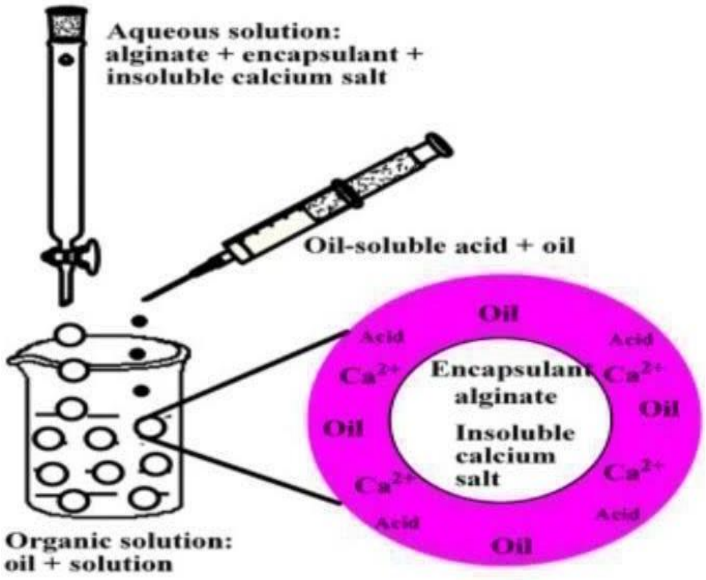

Figure 2.

Emulsion cross-linking method

The medicine was mixed into a gelatine solution that had already been heated to 400 degrees Celsius for one hour. This mixture was then slowly added drop by drop into liquid paraffin that was kept at 350 degrees Celsius, forming a water-in-oil emulsion. The mixture was then stirred at 1500 revolutions per minute for ten minutes. Optionally, it could be stirred again at 150 degrees Celsius for another ten minutes. The spherical beads were then washed three times, first with acetone and then with isopropyl alcohol, and left to dry in the air. After that, the beads were placed in 5 mL of a solution made by mixing aqueous glutaraldehyde with saturated toluene, and the whole setup was heated to 280 degrees Celsius for three hours to strengthen the structure. The beads were then washed again, dried, and kept separate. Finally, the beads were put into a 100 mL solution containing 10 mm glycine and 0.1 percent w/v glutaraldehyde, and heated between 80 and 370 degrees Celsius for ten minutes to remove any leftover glutaraldehyde.[6]

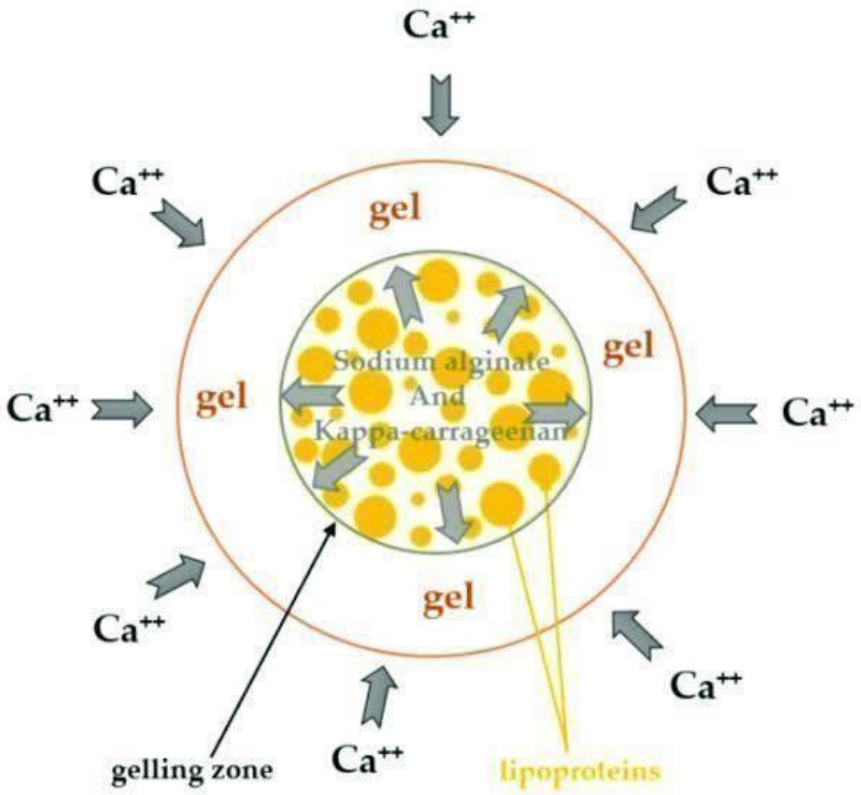

Figure 3.

Characterizations of sodium aliginate

Fourier Transform Infrared Spectroscopy

The mix between the pure drug and the polymer was checked using FT-IR results. The samples were turned into powder and tested as KBr pellets with a Fourier transform infrared (FTIR) device. The pellet was put into the sample holder. The scan was done between the wavelengths of 4000 and 400 cm−1, with a resolution of 4 cm−1 and a scan speed of 1 cm/s.[7]

Surface Morphology Analysis by Scanning Electron Microscopy (SEM)

The beads coated with the drug were placed on a brass stick using sticky tape and coated with a thin layer of gold (3–5 nm) under vacuum in an ion sputter for 75 seconds at 20 kV to make them conductive.

Their shape was then studied with a scanning electron microscope.

Bead Size Measurement

The size of 100 dried beads from each batch was measured using an optical microscope for average size. An optical microscope (Olympus) was used, and the micrometer was checked with a stage micrometer.[8]

Measurement of Buoyancy Property

To check how well the beads float, 100 beads were placed in 100 ml of simulated gastric fluid with a pH of 7.4. The mixture was stirred at 50 rpm for 2 hours using a magnetic stirrer. After 2 hours, the ability of the beads to float was recorded by looking at them. The mixture was considered to float if all beads stayed on top. The floating beads were collected, and buoyancy was calculated using the following formula.[9]

Weight of Floating Beads

$$\text{Buoyancy} = (\text{Weight of floating beads} / \text{Initial weight of beads}) \times 100$$

Drug Content of the Beads

20 mg of drug-loaded beads were placed in 20 mL of phosphate buffer (pH 6.8) in amber vials. They were sonicated for 15 minutes and mixed at 750 rpm for 4 hours in the dark to fully extract the drug. Then, the mixture was spun at 5000 rpm for 15 minutes at 15°C. The amount of drug in the liquid was measured using a validated UV method at 232 nm.[10]

Loose Surface Crystal Study

The microcapsules were studied to find out if there was extra drug on the surface.

100 mg of microcapsules were shaken in 20 ml of pH 7.4 phosphate buffer for 5 minutes and filtered through a 0.45 µm filter. The amount of drug in the liquid was found using a spectrophotometer, which gives the total drug content.[11]

Percent Moisture Loss

The microcapsules were checked for moisture loss to understand their hydrophilic nature.

The initial weight (W1) of the microcapsules was measured before they were placed in a desiccator with calcium chloride at 37°C for 24 hours. The final weight (W2) was noted when the weight stopped changing. The percentage moisture loss was calculated using the formula

$$\text{Percent moisture loss} = (W1 - W2 / W1) \times 100$$[12]

Differential Scanning Calorimetry (DSC)

DSC was used for the pure drug, drug-polymer mix, and optimized microcapsules in a Shimadzu DSC 60 device. The samples were heated between 30 and 300°C at 10°C per minute in a nitrogen atmosphere (flow rate, 20 ml/min).

Swelling Index

The swelling index was calculated by keeping the microcapsules in pH 7.4 phosphate buffer for 12 hours. After soaking, the weight of the swollen microcapsules was noted. The swelling index was found using the formula: Sw = (Wt – Wo / Wo) × 100, where Sw is the swelling percentage, Wt is the weight after soaking, and Wo is the initial weight of the microcapsules.

Determination of DEE

100 mg of beads were crushed in a mortar and pestle. The crushed powder was placed in a 250 ml flask with phosphate buffer (pH 7.4) and left for 24 hours at 37°C with occasional shaking. Then, it was stirred at 500 rpm for 20 minutes. The remaining polymer was removed by filtering through Whatman® filter paper (No. 40). The amount of drug in the filtered solution was measured using a UV–vis spectrophotometer (Shimadzu, Japan) at 233 nm against a blank. The DEE (%) was calculated using the formula: DEE (%) = Actual drug content in beads / Theoretical drug content in beads × 100.[13]

In Vitro Drug Release Studies

The baskets were covered with 100-mesh nylon cloth to prevent beads from passing through. The release rate was measured at 37°C with a 50 rpm speed. 100 mg of beads with an equivalent amount of Vildagliptin were placed in 900 ml of 0.1 N HCl (pH 1.2). The test was run for 2 hours in HCl and then continued for 8 hours in phosphate buffer (pH 7.4). 5 ml of liquid was taken at regular intervals and replaced with fresh solution to keep the sink condition. The collected samples were filtered and diluted to measure absorbance at 233 nm using a UV–vis spectrophotometer (Shimadzu, Japan) against a blank.[14]

Stability Study

The stability of the preparation was analyzed. This microcapsule was evaluated for physicochemical properties, drug content, and in vitro drug release at specified periods (0, 1, 2, and 3 months) to assess the stability.

Applications of sodium alginate beads

Alginate is used in many foods and medical uses because it is safe for the body, not too harmful, not very expensive, and can form a soft gel easily. In the food industry, it helps make food thicker, hold its shape, mix ingredients better, keep things from separating, and improve how food feels. Sodium alginate beads are made by placing sodium alginate in calcium chloride, a process called ionotropic gelation. These beads are good at cleaning water by

sucking up harmful things like heavy metals (like cadmium, lead, and copper), colored dyes from clothes, medicines, and tiny plastic bits. The beads have holes inside, and scientists can add materials like graphene oxide or activated carbon to make them better at cleaning.

Sodium Alginate beads have various pharmacokinetic advantages such as,

a) Increase AUC
b) Sustain drug concentration
c) Enhance nasal absorption
d) Efficient delivery of drugs like insulin into the systemic circulation,
e) Enhance bioavailability
f) Increase mean residence time (MRT) of drugs etc.[15]

CONCLUSION

Sodium alginate beads are used as a way to deliver drugs and offer benefits like more flexibility and easier adjustment of the drug dosage. These beads can be made easily and effectively using a method called ionotropic gelation. However, one issue with these beads is that their loose structure can lead to drug leaking out through the pores during the formation process. Adding another polymer called HPMC K100M helps slow down the release of the drug, making it last up to 12 hours. As the amount of cross-linking agents like aluminum chloride increases, the beads become more spherical in shape. These small spherical particles help improve the effectiveness of drugs like curcumin, which is not very soluble in water and has low bioavailability. The ionotropic gelation method is simple, affordable, and can be used in both lab and industrial settings. This method uses natural building blocks from a substance. Because of these qualities, sodium alginate beads can be a good choice for delivering drugs to specific areas in the body.[16]

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