Microsphere: A Boon in Pharmaceuticals

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ABSTRACT
The present review article introduce about various types of microspheres, different methods of preparation, its applications and also various parameters to evaluate their efficiency. Microspheres are various types like magnetic microspheres, floating microspheres, radioactive microspheres, bioadhesive microspheres, polymeric microspheres, biodegradable polymeric microspheres, synthetic polymeric microspheres and are prepared by methods like spray drying, solvent evaporation, single emulsion technique, double emulsion technique, phase separation coacervation technique, spray drying and spray congealing, solvent extraction. Microspheres have wide range of applications because of controlled and sustained release. Current aim of this review is to study various aspects of the microsphere drug delivery system including method of formulation, evaluation parameter and characterization.

Keywords: Microspheres, Types of microspheres, Method of preparation, Application.

INTRODUCTION

Microsphere is defined as the small spherical free flowing particles which is of size not more than 200 micrometer. It can be injects by 18 or 20 number needle. Generally, microsphere composed of protein or synthetic polymers. A microsphere-based drug delivery system can overcome the problems linked with conventional dosage form and improve the therapeutic action of drug given. Floating microspheres an example of gastro-retentive drug delivery systems based on non-effervescent approach. Magnetic microspheres Use for target to tumors. The clearance kinetics, tissue distribution, metabolism i.e., kinetics and cellular interaction of the drug are strongly influenced by the behavior of the Carrier. The exploitation of these changes in pharmacodynamics behavior may lead to enhanced therapeutic efficiency.1-2

Advantages of microsphere
1. Protect the drug from enzymatic and photolytic cleavage hence stable for long time.
2. Decrease dose and increase efficacy.
3. Drug release is constant hence prolonged therapeutic effect.
4. Increase solubility of the poorly soluble drug due to particle size reduction.
5. Provide constant drug concentration in blood there by less or no toxicity.
6. Provides prolonged therapeutic effect.
7. Improve the patient compliance by reducing the dosing frequency.
8. The spherical shape and smaller size makes them to be injected into the body.
9. The morphology of microspheres shows variability in controlled release of drug.
10. Conversion of oil and other liquids to solids for ease of handling.

Disadvantages of microsphere
1. The altered release from the formulations.
2. Thee release rate of the controlled release dosage form may vary from a variety of factors like GI content and the rate of transit though gut.
3. Differences in the release rate from one dose to another due to manufacturing faults.
4. Microsphere contains large amount of drug dose so if any change in physical integrity of microsphere that may shows potential toxicity.
5. Dose dumping: loss of physical integrity by various factors like manufacturing faults, crushing and co administring with other drugs.
6. Drug Release reproducibility is difficult.
Types of Microsphere

1. Bioadhesive microspheres
2. Magnetic microsphere
3. Floating microspheres
4. Mucoadhesive microspheres
5. Radioactive microspheres
6. Polymeric microspheres
   A. Biodegradable polymeric microsphere
   B. Synthetic polymeric microsphere

Bioadhesive microspheres

The word bioadhesive means any substance which binds to biological substance like mucosal membrane. When bioadhesive drug delivery device attached to a biological membrane it provides prolonged contact at site of administration. Due to the prolonged contact at the site of administration there will be greater absorption of particular drug and prolonged residence time thus it reduce the dosing frequency and improve the patient compliance. Microsphere, nanospheres, liposome, nanoparticle drug delivery system which modifies the absorption and release pattern of the drug. Microsphere is one of the most important part of these particulate drug delivery system.³

Magnetic microsphere

Magnetic microsphere is very much important which target the drugs to the particular disease site. In magnetic microsphere the large amount of release circulating drug can be replaced with small amount of magnetically target drug. After that microsphere is injected in the body. The high strength magnetic field is applied externally over the target organ to gather microsphere at the target site. Therapeutic magnetic microsphere delivers the chemotherapeutic agent to the liver tumor.⁵

Floating microspheres

The bulk density of floating microspheres is less than the gastric fluid so it floats over the gastric content in stomach without affecting gastric emptying rate. If the system is floating on gastric content it produce release of drug at desirable rate & increases stomach residence time. The drug ketoprofen is given in floating microsphere. Floating microspheres reduces the chances of dose dumping and provide prolonged therapeutic effect.⁵

Mucoadhesive Microspheres

Mucoadhesive microspheres are defined as the microsphere which are of size 1-1000 nm made up of mucoadhesive polymers. Mucoadhesive microspheres has following additional advantages like enhanced bioavailability & efficient absorption of drugs. Mucoadhesive microspheres can adhere to the any mucosal tissue membrane of eye, nasal cavity, GIT & thus provides great possibilities of systemic & controlled released of drugs.⁶

Radioactive microspheres

Radioactive microsphere is of size 10-30 nm. Generally radioactive microspheres are differ from other drug delivery systems. The different types of radioactive microsphere are α Emitters, β emitters, γ emitters. There is no radioactivity released from microsphere. Radioactive microsphere are injected to the arteries that lead to tumor of interest. That produce high rate of radiation at the target site without damaging surrounding tissues.

Polymeric microspheres

Biodegradable Polymeric microsphere

Biodegradable polymeric microsphere are made up of biodegradable, biocompatible & bioadhesive polymer like starch. When this biodegradable polymer comes in contact with aqueous medium it swells & produce gel like structure. Due to this property biodegradable polymer prolongs the residence time. The release of drug from biodegradable polymeric microsphere is controlled by concentration of polymer & release pattern in a sustained manner.⁷

Synthetic polymeric microsphere

Synthetic polymeric microsphere are widely used in field of clinical application, moreover that also used as bulking agent, fillers, embolic particles, drug delivery vehicles. But here the main disadvantage is that when synthetic polymeric microsphere is injected to body that might tend to migrate from the injection site to surrounding tissue organ that may lead to potential at risk and toxicity.⁸

Method of Preparation

The choice of method for the preparation of microsphere depends upon the nature of drugs and polymer used and it also depends on the duration of therapy. There are several important chemical factor that may be controlled in microsphere manufacture are

- Molecular weight of polymer
- Release of active reagent with a good control over a wide time-controlled particle Size and dispensability in aqueous vehicles for injection
- Reproducibility
- Total mass of drug and polymer
- Final product should be non-toxic.

Single emulsion technique

In single emulsion technique first the natural polymers are dissolved in aqueous media followed by dispersion of heated oil. i.e. non aqueous medium that lead to the formation of single emulsion. After that cross linking is carried out in two ways.
Cross linking by heat: by adding the dispersion into Heated oil, but it is unsuitable for the Thermolabile Drugs.

Chemical cross-linking agents: chemical cross-linking is carried out by chemical cross-linking agents like of glutaraldehyde, di acid chloride. But here disadvantage of excessive exposure of active ingredient to chemicals if added during the preparation. After the crosslinking it is subjected to centrifugation, washing & separation. By using 25% glutaraldehyde solution as a crosslinking agent metformin hydrochloride microsphere were prepared.9–10

Double emulsion technique
As the name suggests that there will be formation of double emulsion emulsions or the double emulsion of type w/o/w and is best suited to water Soluble drugs, peptides, proteins and the vaccines. In this method of microsphere preparation natural and semi synthetic polymer can be used. In single emulsion the continuous phase is generally made up of polymer solution which eventually encapsulates of the protein Contained in dispersed aqueous phase.11

After the formation of single emulsion, it is subjected to homogenization before addition to aqueous solution of the polymer that results in the formation of a double emulsion. After that the emulsion undergoes to solvent removal either by solvent evaporation or by solvent extraction.

Ex: microspheres containing leutinizing hormone releasing hormone (LH- RH) Agonist, vaccines, proteins/peptides are successfully prepared by double emulsion method

Polymerization
Mainly two techniques are using for the preparation of Microsphere are classified as:
A. Normal polymerization
B. Interfacial Polymerization

Normal Polymerization
In a process of bulk polymerization monomer mixture of monomer combined with initiator or catalyst usually heated to initiate polymerization. Generally, suspension polymerization is occurs at low temperature which is also known as polymerization in which heating the monomer mixture with active drug as droplets dispersion in continuous aqueous phase. Microspheres of size less than 100 micrometer are obtained by suspension polymerization. Emulsion polymerization is also occurring at low temperature but it is differentiated from the suspension polymerization because the presence of initiator in aqueous phase.12

Interfacial Polymerization
It involves the reaction of various monomers at the interface between the two Immiscible liquid phases to form a film of polymer that essentially envelops the dispersed phase. In this technique two reacting monomers are employed; one is dissolve in continuous phase while other is disperse in continuous Phase (aqueous in Nature) throughout which the because of solubility of formed polymer in the emulsion droplet. That is formation is monolithic type of carrier.

Phase separation and Coacervation method
It is the simple separation of a micro molecular solution into two immiscible liquid Phase. This method is used to encapsulate water soluble drugs e.g. peptides, proteins. Method includes the dissolution of polymer in a suitable solvent followed by drug dispersion. Phase separation is then accomplished by changing the solution conditions by the salt addition, odd-solvent addition, addition of the incompatible polymer or change in PH.13
The principle of Coacervation is decreasing the solubility of the polymer in organic phase to affect the formation of polymer rich phase called the coacervates. Here in this technique the polymeric solutions containing drug dispersion with incompatible polymer is added to the system which makes first polymer to phase separate and engulf the drug particles. Generally, matrix type preparation are prepared by this method for hydrophilic drug e.g. steroids, addition of non-solvent results in the solidification of polymer. Addition of sodium sulphate to the solution of chitosan in acetic acid resulted in decreased solubility of chitosan, leading to precipitation of chitosan as a poorly soluble derivative.

**Spray drying**

In spray drying method of microsphere preparation evaporation is the basic mechanism while spray congealing is the inversion from liquid to solid phase. Both processes are similar, except for energy flow spray drying is the most widely used Industrial process involving particle formation and drying. Here in spray drying first over polymer is preferred in volatile organic or volatile solvent like of chloroform and acetone and dichloro methane. After that the drug which is in solid form is dissolved in polymer solution under high speed homogenization. This dispersion is then atomized in a stream of hot air, that results in the formation of small droplets. Solvents on the surface of small droplet is you are operated due to continuously flow of hot air leading to the formation of small microsphere. This technique is very useful to encapsulate various penicillins.\(^\text{14-16}\)

There are three steps involved in spray drying

i. Atomization

ii. Mixing

iii. Drying

Spray drying technique is also useful for preparing chitosan microspheres In 1999 He et.al. Used formaldehyde as a crosslinking and also reported a novel method in which cimetidine and famotidine were entrapped in microspheres prepared by spray drying of multiple emulsion (o/w/o or w/o/w). They found that the release of the drugs from microspheres this novel method was significantly sustained as compared to those prepared by conventional spray drying or o/w emulsion method. In a spray-drier under different experimental conditions. Solid microspheres were collected into final bottom vessel spray-drier.\(^\text{14-16}\)

**Solvent extraction**

This method involves removal of organic phase by extraction of the organic solvent. The method involves water miscible organic solvents such as isopropanol. Organic phase is removed by extraction with water. This process reduces the time required for hardening of microsphere. Another variation of this process involve directly addition of drug to the polymer the rate of solvent removal by extraction method depends on the
temperature of water, ratio of emulsion volume to the water and the solubility profile of the polymer.\textsuperscript{17}

**Wax coating and hot melt method**

Here in this technique first our polymer is dissolved in appropriate dispersion medium after that slowly cooled to form microsphere. The polymers which having low melting point fabricated into microspheres by this technique Easily. For coating and coring of particle wax is use mostly.

**Emulsion Solvent evaporation**

![Figure 4: Emulsion solvent evaporation](image)

This technique includes the drug is dissolved in polymer solution of chloroform and the resulting solution is added to aqueous phase containing 0.3 % sodium of PVP as Emulsifying Agent. The above mixture was agitated continuously then the drug and polymer was transformed into fine droplet which solidified into rigid microspheres by solvent evaporation and then collected by filtration and washed with demineralized water and desiccated at room temperature for 24 Hrs.\textsuperscript{19}

**Evaluation Parameters For Microspheres**

1. Characterization
2. Particle size & shape
3. Isoelectric Point
4. Density determination
5. Angle of contact
6. Electron spectroscopy for chemical analysis
7. Alternated total reflectance fourier transform infrared spectroscopy
8. Drug release
   a) In vitro method
      a) Interface diffusion system
      b) Modified Keshary Chien cell
9. Dissolution studies
   a) Vivo methods
   b) In vitro In vivo correlation

**Characterization**

The characterization of microsphere is an important phenomenon that helps to design of appropriate carrier for the delivery of the drug or protein molecules. These microspheres have different microstructures. These microstructures determine the release and the stability of the carrier.\textsuperscript{20}

**Particle size & shape**

light microscopy and scanning electron microscopy widely used to visualise size and determine shape of microsphere. Both can be used to determine the shape and outer structure of microparticles. LM provides a control over Coating parameters in case of double walled microspheres. SEM produce higher resolution in contrast to the LM. Confocal fluorescence microscopy is used for the structure characterization of multiple walled microspheres. on another hand two non instrumental analytical technique laser light scattering & multisize couler counter used For the morphological characterization of microsphere.\textsuperscript{21}

**Isoelectric Point**

The electrophoretic mobility of microsphere can be determined with the help of apparatus known as micro electrophoresis and on the basis of electrophoretic mobility isoelectric point can be determined. The electrophoretic mobility can be related to surface contained charge, ionisable behaviour or ion absorption
nature of the microspheres. The mean velocity at different pH values ranging from 3-10 is calculated by measuring the time of particle movement over a distance of 1 mm.22

Density determination

The density of the microspheres can be measured by using a multi volume pycnometer. Here first power sample of microsphere of which density to be determined is accurately where it and placed into multivolume pycnometer. Helium is inserted at a constant pressure in the chamber and allowed to expand. This expansion results in a decrease in pressure within the chamber. Two consecutive readings of reduction in pressure at different initial pressure are noted. From the pressure reading density of the microsphere can be determined.22

Angle of contact

The angle of contact can be measured at the solid/air/water interface. The advancing and receding angle of contact are measured by placing a droplet in a circular cell mounted above objective of inverted microscope. It is a very fast process generally contact angle is measured at 200°C within a minute of deposition of microsphere solid/air/water interface.

Spectroscopy for chemical analysis

Electron spectroscopy for chemical analysis (ESCA) used to determine surface chemistry of microsphere. ESCA can be used to determine of the atomic composition of the surface. The spectra obtained using ECSA can be used to determine the surface degradation of the biodegradable microspheres.23

Alternated total reflectance fourier transformed infrared spectroscopy

FT-IR provides information the degradation of the polymeric matrix of the carrier system. The surface of the microspheres is investigated measuring alternated total reflectance (ATR). The beam of IR radiation reflected many times from the sample to get IR spectra. The ATR FTIR gives idea about the surface composition of the microspheres.

Drug release

In vitro method

Drug release study is very important parameter which depends upon the release characteristic of the microsphere. For this purpose, a number of in vitro and in vivo techniques have been reported. In vitro drug release studies have been employed as a quality control procedure in pharmaceutical production, in product development etc. The dosage form in this method is made to adhere at the bottom of the beaker containing the medium and stirred uniformly using overhead stirrer.23

Diffusion system

This method of microsphere preparation is discovered by darden & Tomlinson. It consists of four compartments. The compartment a represents the oral cavity, and initially contained an appropriate concentration of buffer. The compartment B represents the buccal membrane, contained 1-octanol, and compartment C represents body fluids, contained 0.2 M HCl. The Compartment D represents protein binding which also contained 1-octanol. Before use, the aqueous phase & 1-octanol were saturated with each other. Samples were withdrawn and returned to compartment A with a syringing 1-octanol. Before use, the aqueous phase and 1-octanol were saturated with each other. After that samples were withdrawn and returned to compartment A with a syringe.24

Modified Keshary Chien cell

A specialized apparatus was designed in the laboratory. It consists of a Keshary Chien cell which contains distilled water (50ml) at 370°C as dissolution medium. TMDDS (Trans Membrane Drug Delivery System) was placed in a glass tube fitted with a 10# Sieve at the bottom which reciprocated in the medium at 30 strokes per min.25

Dissolution studies

Standards USP or BP dissolution apparatus have been used to study in vitro release Profiles using both Rotating elements, basket 28, 29& paddle 25, 26, 27. The Dissolution Medium used for the study varied from 100-500 ml and speed of rotation from 50-100 rpm.26

In vivo methods

The most commonly used methods include in vivo studies using animal models, buccal absorption tests, and perfusion chambers for studying drug permeability. Methods for studying the permeability of intact mucosa consist of techniques that shows the biological response of the organism locally or systemically.

In vivo vitro correlation

Correlations between in vitro dissolution rates and the rate & extent of availability as determined by blood concentration & or urinary excretion of drug or metabolites are referred to as “in vitro-in vivo correlations”. Such correlations allow one to develop product specifications with bioavailability.

APPLICATIONS OF MICROSPHERE

Vaccine delivery

The vaccine is a form of protection against the microorganism or its toxic product. An ideal vaccine must satisfy the requirement of efficacy, safety and convenience in application and cost. Generally biodegradable delivery systems for vaccines that are given by parenteral route may overcome the shortcoming of the conventional vaccines or reduces the problems associated with the conventional vaccine. It act as a career for vaccines delivery since they offer specific advantages including:

- Improved antigenicity by adjuvant action
- Modulation of antigen release
Microspheres are intimate contact. Immunological reactions that se porous microspheres on, and can be self-provided therapeutic effect for prolonged period.

Bioavailability. The gastroretentive drug delivery system systems for better absorption and enhanced the difficulties are faced in designing controlled release valued asset For dosage forms, there are several variable process & ability to control forms. Gastric emptying of dosage form is extremely stomach for a prolonged period than conventional dosage have float over the gastric contents and remain in the stomach for a prolonged period. In which floating systems are low formulations such as creams, lotions and powders.

Microsphere plays very important role in topical drug delivery system bioadhesive microsphere are used which has great importance because of additional advantages: efficient absorption and enhanced bioavailability of the drug, a much more intimate contact. Due to prolonged contact with nasal mucosal membrane there will be prolonged therapeutic effect so that the dosing frequency is reduced. IN delivery is needle-Free, non-invasive, and essentially painless, does not require sterile preparation, and can be self-administered. For treatment and prevention of nasal symptoms E.g. Rhinitis, allergy, decongestion and local Inflammation etc. Imaging

The particle size plays an critical role in determining the imaging of particular sites. The particles which are injected intravenously apart from the portal vein it will become entrapped in the capillary bed of the lungs. This phenomenon is exploited for the scintiographic imaging of the tumor masses in lungs using labeled human Serum albumin microspheres. Targeted drug delivery

Generally microsphere shows problem residence time at the contact side and therefore provides therapy effect for prolonged time. Microspheres have been Developed for oral, buccal, ocular, rectal, nasal and vaginal routes for either systemic or local effects. There are number of drugs which are given by different route of administration and having good targeting effect some of example are given in below table

| Drug     | Route of administration | Polymer used                                      |
|----------|-------------------------|-------------------------------------------------|
| Acyclovir| Ocular                  | Chitosan                                        |
| Furosemide| Nasal, GI               | Degradable strachmicspheres and lyso phosphatidylcholine polyglycerol esters of fatty acids Hyaluronic acid esterase |
| Insulin  | Vaginal                 |                                                 |

Topical drug delivery

Microsphere plays very important role in topical drug Delivery system. These microsphere having capacity to encapsulate wide range of active ingredients such as emollients, fragrances, essential oils etc., are used as the topical carries system further, these porous microspheres with active ingredients can be incorporated into formulations such as creams, lotions and powders.

Gastroretentive controlled release system

In which floating systems are low-density systems that have float over the gastric contents and remain in the stomach for a prolonged period than conventional dosage forms. Gastric emptying of dosage form is extremely variable process & ability to control the emptying time is valuable asset For dosage forms, there are several difficulties are faced in designing controlled released systems for better absorption and enhanced the bioavailability. The gastroretentive drug delivery system floats over the gastric content & release drug at slow rate & provide therapeutic effect for prolonged period.

- Chitosan

Biomedical applications

Microencapsulation has also been used medically for the encapsulation of live cells and vaccines. Biocompatibility can be improved by the encapsulation of artificial cells And biomolecules like peptides, proteins, and hormones, which can prevent unwanted immunological reactions that would lead to inactivation or rejection.

Pharmaceuticals application

A number of pharmaceutical microencapsulated products are currently on the market. Such as aspirin, theophylline and its derivatives, pancrelipase, vitamins,
Anti hypertensives, potassium chloride, progesterone, and contraceptive hormone combinations. \(^{39-41}\)

Microencapsulated KCL is used to prevent gastrointestinal complications associated with potassium chloride. Most encapsulation processes are expensive and require significant capital investment for equipment. \(^{42-45}\)

Table 2: list of various marketed products containing microsphere

| Drug         | Commercial Name | Company         |
|--------------|-----------------|-----------------|
| Resperidone  | CONSTA®         | Janseen         |
| Naltrexone   | VIVITROL®       | Alkermes        |
| Leupropride  | LUPRON DEPOT®   | TAP             |
| Octreotide   | SANDOSTATIN®    | Novartis        |
| Somatropin   | NUTROPIN®       | Genentech       |
| Triptorelin  | TRELSTAR®       | Pfizer          |
| Buserelin    | SUPRECULAR®     | Sanofi-aventis  |
| Lanreotide   | SOMATULINE®     | Ipsen-beaufour  |
| Bromocriptine| PARLODEL LAR®   | Novartis        |
| Monocycline  | ARESTIN®        | Orapharma       |

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CONCLUSION

Microspheres are better choice of drug delivery system than many other types of drug delivery system. In future by combining various other strategies, microspheres will find the central and significant place in novel drug delivery, microspheres offer several improvements over existing technologies. In recent years there have been increasing numbers of studies in which microspheres have been used in more diverse applications and it is evident that the Range of potential applications is enormous. In Microsphere is a short term but it is having wide applications in drug delivery systems to get desire biological activity. By combining various strategies, microspheres will find central place in novel drug delivery system mainly particularly in cell sorting, diagnostics and genetic engineering. From the study it is proved that microspheres act as a boon in pharmacueticals.

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