INTERNATIONAL JOURNAL OF CURRENT ADVANCED RESEARCH
ISSN: O: 2319-6475, ISSN: P: 2319-6505, Impact Factor: 6.614
Available Online at www.journalijcar.org
Volume 12; Issue 05(A); May 2023; Page No. 2057-2062
DOI: http://dx.doi.org/10.24327/ijcar.2023.2062.1451

Research Article

NANOSUSPENSIONS - A NOVEL APPROACH FOR VARIOUS DRUG DELIVERY SYSTEMS AND ENHANCED SOLUBILITY

Balusu Haarika*, Hepsiba Rani CH and Divya Theja P

Department of Pharmaceutics, Sarojini Naidu Vanita Pharmacy Maha Vidyalaya, 12-5-31/32, Vijayapuri Colony, Tarnaka, Secunderabad, 500017, Telangana, India

ARTICLE INFO

Article History:
Received 15th February, 2023
Received in revised form 7th March, 2023
Accepted 13th April, 2023
Published online 28th May, 2023

Key words:

Nanosuspension, solubility, bioavailability, preparation, characterization and application.

ABSTRACT

Nanosuspensions refer to pharmaceutical active ingredient particles that are present in a liquid phase and are dispersed in a size below 1µm. The development of new drugs is happening rapidly, resulting in a variety of promising drug candidates that work well, but do not dissolve easily in water. Nanosuspension is a possible solution to the issues that arise when working with drugs that are poorly water- and lipid-soluble because of its unique properties and submicron particle size. BCS Class II drugs have low solubility, but the use of nanotechnology increases their solubility and bioavailability. Preparing nanosuspension is a straightforward process applicable to all drugs that are insoluble in water. A nanosuspension offers a comprehensive solution to the issue of limited solubility and availability of drugs. Apart from that, its impact on pharmacokinetics paves the way for better efficacy and safety of medicines. The interaction of this technology takes place at a molecular level, making it highly specific in targeting cells and tissues, with the possibility of clinical applications yielding the most favourable therapeutic outcomes with minimal adverse effects. In this article review, the ways of preparing, characterizing and application of nanosuspensions are discussed.

Copyright© The author(s) 2023. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

INTRODUCTION

Advancements in the field of drug discovery have led to the development of new and effective ways to deliver drugs to the body, such as through nanosuspensions. Due to its unique properties and sub-micron particle size, these materials can be used to address various formulation and delivery issues[(1)]. Some of the techniques that can be utilized to formulate these are media mills, high-pressure homogenizer, and emulsion-solvent evaporation.

The stability of the solution and the resuspendability of the nanosuspension are some of the factors that are considered when it comes to the production and scale-up of these materials. Currently, the research in this field is focused on the development of new and effective drug delivery systems for multiple applications, such as oral, nasal and ocular[(2)].

This article provides an overview of the various steps involved in the production of nanosuspensions, including the characterization, preparation, and post-production procedures. It also covers the clinical applications of these materials.

Benefits of Using Nanosuspensions:[(3-5)]

1. Improve the ability of drugs to dissolve and be absorbed by the body.
2. Hydrophilic medications are appropriate for use.
3. It is possible to increase the drug loading capacity.
4. Modifies the drug regimen, adjusting the frequency of medication administration, or switching to a lower dose form of the drug.
5. Increase the durability and steadiness of medications through improvements in their physical and chemical properties.
6. Passive drug targeting is made possible with this.

Drawbacks of Nano Suspensions

1. Sedimentation and physical stability.
2. During handling, one must exercise caution as it is quite large and cumbersome.
3. It is essential to take the correct dosage of medication. Taking an incorrect dose of medicine can have negative consequences.
4. Uniformity in dose cannot be attained.

Preparation Techniques for Nanosuspension

Nanosuspensions offer a simpler and more cost-effective alternative to conventional drug carriers like liposomes. They are particularly useful for poorly soluble drugs and result in a more physically stable product. The two methods of manufacturing nanosuspensions are the Top-down process technology and the Bottom-up process technology.

Corresponding author:* **Balusu Haarika
Department of Pharmaceutics, Sarojini Naidu Vanita Pharmacy Maha Vidyalaya, 12-5-31/32, Vijayapuri Colony, Tarnaka, Secunderabad, 500017, Telangana, India

Bottom up process

The technology conventionally used for precipitation (Hydrosols) is referred to as Bottom up. This method entails dissolving the drug in an organic solvent and combining the solution with a miscible anti-solvent. When mixed with water-solvent, the drug has low solubility, thereby leading to precipitation. Additionally, high shear processing can be combined with precipitation. Baxter International Inc. holds the registered trademark for the Nan edge process. In order to break down materials through high shear and/or thermal energy [(6)], the corporation and its affiliated companies depend on the precipitation of friable substances. This is achieved through fast precipitation and high-pressure blending. When a drug solution is swiftly added to an anti-solvent, the mixed solution becomes suddenly supersaturated and results in the generation of fine crystalline or amorphous solids. When the solubility of an amorphous material is surpassed, it is more likely for precipitation to occur at a high level of super saturation.

Top Down technology

The preparation of nanosuspensions for poorly water-soluble drugs has been facilitated through the utilization of high pressure homogenization [(7)]. This method entails the forced application of pressure to drug and surfactant suspensions via a nanosized aperture valve in a specialized homogenizer. Such a technique operates on the principle of cavitation within the aqueous phase. Converting drug micro particles to nanoparticles can be achieved through the use of high cavitation forces from particles. However, a major drawback of this approach is that it requires small sample particles before loading and multiple homogenization cycles.

High Pressure Homogenization

Preparing nanosuspension for certain drugs that do not dissolve well in water has been done through high pressure homogenization (HPH) technique[(8)]. This method utilizes force and pressure to push a mixture of the drug and surfactant through a tiny valve in a high pressure homogenizer to create a smaller particle size. The underlying principle of HPH is centered on the creation of cavitation within the liquid phase. The drug microparticles can be transformed into nanoparticles due to the powerful forces of cavitation particles. However, the drawback is that the technique requires small sample particles for loading and multiple homogenization cycles[(9)].

Homogenization in aqueous media

Back in 1999, R.H. Muller came up with a newfangled technology that utilized a high pressure homogenizer with a piston-gap mechanism. To execute this technique, they would forcefully push a solution with both a drug and a surfactant through an incredibly small valve within the homogenizer. This entire process ultimately results in the creation of nanoparticles[(10)].

Fundamental concept

Built upon the principle of cavitation, this technique involves the rapid movement of a dispersion contained within a cylinder measuring 3cm in diameter through an exceptionally small opening with a diameter of 25µm. Bernoulli's law establishes that the flow rate of liquid in a closed system remains uniform across every cross section. When the diameter of water reduces from 3cm to 25µm, it causes a rise in the dynamic pressure and a drop in the static pressure below water's boiling point at room temperature. This leads to the formation of gas bubbles, which collapse upon leaving the gap (known as cavitation) and returning to normal air pressure. As a result, water begins to boil at room temperature. The force of cavitation particles is strong enough to transform drug micro particles into nanoparticles.

Benefits

1. The processed materials do not undergo any form of erosion.
2. This is relevant to drugs that exhibit low solubility in both water and organic compounds.

Drawbacks

1. Drug pre-treatment through techniques such as micronization is necessary.
2. The expense of dosage forms is escalated due to necessary utilization of costly instruments.

Homogenization in non-aqueous media (Nanopure)

Suspensions that have been homogenized in media that are devoid of water or have mixtures of water like PEG 400 and PEG 1000 are called Nanopure. The process of homogenization can take place at room temperature, temperatures as low as 0°C, and even below freezing point (-20°C). This process is referred to as deep freeze homogenization[(11)].

Nanoedge Technology

The integration of precipitation and homogenization gives rise to Nanoedge technology, which operates on the same fundamental principle as its individual components[(12)]. Nanoedge technology offers a solution to the lingering issues of long-term stability and crystal growth that commonly accompany precipitation technique. This novel technology facilitates the production of nanosized particles that exhibit superior stability within shorter turnaround times.

Nanojet technology

Nanojet technology has revolutionized the field of drug delivery by enabling precise and targeted administration of drugs. With the use of Nanojet, medicines can be targeted to specific cell types, reducing side effects and increasing efficacy. This technology is also being researched for use in non-medical applications such as agriculture and nanoelectronics. Overall, Nanojet has the potential to significantly impact various industries and improve quality of life for many people. Rewritten text: The use of Nanojet has transformed how drugs are delivered, providing a level of precision and accuracy that was previously impossible. This innovative technology specifically targets certain cell types, reducing the risk of side effects while increasing effectiveness. While the medical field has already seen the benefits of Nanojet, researchers are also exploring its potential in other areas such as agriculture and nanoelectronics. The impact of Nanojet expands beyond just healthcare, with the potential to improve various industries and ultimately enhance quality of life for many individuals.

Opposite stream technology, or high pressure homogenization, involves dividing a suspension stream into multiple parts within a chamber. These parts collide with each other at high pressure, leading to a reduction in particle size[(13)].

Milling Techniques

Media milling

Media milling is a process used to refine materials by reducing their particle size using specialized equipment. The technique is used in a wide range of industries, including pharmaceuticals, food processing, and cosmetics. During media milling, the material is introduced into a chamber that contains small beads or balls. The beads are then agitated, causing them to collide with the material and break it down into smaller particles. This process allows for more precise control over the particle size and results in a more uniform product. Additionally, media milling can be used to create materials with unique properties, such as increased surface area or improved solubility.

Liversidge (1992) was the pioneer of this technique that involves the preparation of nanosuspensions through the use of high shear media mill[(14)]. The process is executed by charging the milling chamber with milling media, water, drug, and stabilizer which is rotated at an extremely high shear rate under a controlled temperature for a duration of 2-7 days [(15)]. The milling medium utilized includes highly cross-linked polystyrene resin, Zirconium oxide, or glass. As the milling media collides with the drug, it creates intense shear forces that cause micro particles to break down into nanosized particles.

Benefits

1. Nanosuspensions, both very diluted and highly concentrated, can be created by manipulating drug quantities ranging from 1 mg/ml to 400 mg/ml.
2. The ultimate nanoproduct is of a nanoscale distribution.

Drawbacks

1. Implementing the media milling method can be a lengthy process.
2. Particles of micrometer size are present in some fractions.
3. Scaling up the mill is a challenging task, primarily because of its considerable size and weight.

Dry Co- grinding

Dry milling is a popular method used nowadays to prepare nanosuspensions. Unlike other methods, it doesn't require any organic solvents and is quite cost-effective. Co-grinding is a technique that falls under the umbrella of dry milling, wherein the physicochemical properties and dissolution rate of drugs that aren't readily soluble in water are enhanced. This improvement is attributed to an increase in the surface polarity of the drug and the transformation from a crystalline to an amorphous form.

Benefits

1. This procedure is simple and does not necessitate the use of any organic solvents.
2. Requires minimal time for grinding.

Drawbacks

1. Generates residue of media milling.

Emulsification-Solvent Evaporation Technique

The method involves first preparing a drug solution, then emulsifying it into a non-solvent liquid. By evaporating the solvent, the drug is able to precipitate. The degree of crystal growth and particle aggregation may be adjusted by using a high-speed stirrer to generate high shear forces.

Precipitation

Over the past ten years, there has been a rise in the use of precipitation for making microparticles, especially for drugs that are not soluble [(16)]. The procedure involves dissolving the drug in a solvent, which is then combined with a compatible anti-solvent in the presence of surfactants.

By promptly introducing a drug solution into the anti-solvent, there is a sudden surge of drug saturation resulting in the creation of either ultra-fine crystalline or amorphous drug solids[(17)].

Benefits

Simple, cost effective and easy to scale up.

Draw backs

One way to control the growth of crystals is by adding surfactants. Additionally, any drug used must have the ability to dissolve in at least one type of solvent.

Supercritical Fluid Process

By employing solubilization and nanosizing technologies using the super critical fluid process, the reduction in particle size has been obtained. Super critical fluids, which are dense fluids that are noncondensable, possess a greater temperature and higher pressure than their critical temperature and pressure respectively. This process facilitates the reduction of drug particles to sub-micron scale. A breakthrough has been made in the SCF technique which involves making a suspension of nanoparticles with a diameter ranging from 5 to 2000nm [(18)]. However, the effectiveness of this technology is limited in the pharmaceutical industry due to the low solubility of drugs and surfactants in supercritical CO_2 and the high pressure required for these processes.

Melt Emulsification Method[(19)]

The drug is incorporated into a stabilizer-based aqueous solution and heated to a temperature exceeding its melting point in order to produce an emulsion. Throughout this procedure, the temperature of the emulsion is consistently above the drug's melting point, and the sample holder is covered in a heating tape equipped with a temperature regulator. The emulsion cooled slowly to normal temperature or on ice- bath.

Benefits

Organic solvents are avoided during production process.

Drawbacks

The process of forming bigger particles and less flexible items differs from solvent evaporation.

Lipid Emulsion / Microemulsion Template[(20-22)]:

For drugs soluble in either volatile organic solvents or partially water miscible solvents, this method is commonly used. The process involves dissolving the drug in an appropriate organic solvent and subsequently emulsifying it in an aqueous phase using appropriate surfactants. By reducing the pressure, the organic solvent was evaporated at a slow pace. This led to the formation of drug particles which

precipitated in the aqueous phase, ultimately resulting in an aqueous suspension of drug particles of a required particle size. Diluting this suspension can lead to the creation of nanosuspensions. In addition, micro emulsions can serve as effective templates for producing nanosuspensions. Micro emulsions consist of two liquids that are usually incompatible, such as water and oil, which are mixed and stabilized by a special layer of surfactant and co-surfactant. The resulting mixture is both stable and uniform. In order to make a drug nanosuspension, the medication can be added to the micro emulsion during the initial mixing process or later after pre-forming. Diluting the micro emulsion will create the desired drug nanosuspension. Lipid emulsions offer a variety of benefits as templates for nanosuspension formation. One advantage is their ease of production, achieved by controlling the emulsion droplet. Additionally, they are highly scalable. However, it is important to note that the use of organic solvents can have a negative impact on the environment, and the process often requires large amounts of surfactant or stabilizer. To prepare Griseofulvin nanosuspension, the micro emulsion technique is utilized, incorporating water, butyl lactate, lecithin, and the sodium salt of taurodeoxycholate.

Benefits

1. Enhanced dissolution of drugs.
2. Prolonged shelf life.
3. The production process is not complicated.

Drawbacks

1. The utilization of dangerous chemicals is causing concern.
2. Excessive application of surfactants and stabilizers.

Solvent evaporation[23]

The preparation of polymer solutions and emulsions in volatile solvents is the basis of the solvent evaporation method. Previously, dichloromethane and chloroform were commonly used for this purpose, but have recently been replaced by ethyl acetate due to its superior toxicological properties. After the emulsion is formed, the solvent is evaporated, resulting in the conversion of emulsion into a nanoparticle suspension. This suspension then diffuses through the continuous phase of the emulsion. Standard techniques for creating emulsions involve two main approaches for generating either single-emulsions, such as oil-in-water (o/w), or double-emulsions, such as (water-in-oil)-in-water, (w/o)/w. These techniques necessitate the utilization of high-speed homogenization or ultrasonication, then solvent evaporation by continuous magnetic stirring at room temperature or under reduced pressure. The collection of solidified nanoparticles involved ultracentrifugation followed by a wash with distilled water to eliminate any surfactants or other additives. These particles were then lyophilized. The particle size was affected by various factors, including the concentration of polymer, stabilizer, and homogenizer speed.

Nanosuspension Formulation[24]

The preparation of a nanosuspension formulation necessitates the inclusion of a stabilizer or surfactant, an appropriate solvent system, and additional ingredients.

Stabilizers

To ensure optimum performance of a solute or drug particle, stabilizers are employed to wet its surface and prevent Ostwald ripening and agglomeration. Physical stability is critical in this regard. A range of stabilizers are commonly used for this purpose, including poloxomers, lecithin, cellulosic, povidone and polysorbate (Span/Tween series).

Organic solvent

Nanosuspensions are typically created using organic solvents when relying on emulsion or micro emulsion approaches. Despite the physiologic and environmental dangers of certain solvents, there are a number of water miscible options that are considered less hazardous. These include methanol, ethanol, chloroform, and isopropanol, as well as partially water miscible solvents like ethyl acetate, ethyl formate, butyl lactate, triacetate, propylene carbonate, and benzyl alcohol. As a result, these solvents are often used as alternatives to dichloromethane, which is a known hazardous solvent.

Additional ingredients

The application of various components hinges on the mode of delivery or physical and chemical qualities of the intended medication. However, typical enhancers like buffers, salts, polyols, osmogents and cryoprotectants are often utilized.

Nanosuspension Charachterisation

Various key elements of nanosuspensions are analysed, such as their physical appearance, colour, scent, purity levels, particle size, zeta potential, crystalline features, dissolution rates, and in vivo responses. These vital assessment methods are important in understanding the quality and efficiency of nanosuspensions.

Average size of particles and their distribution

Nanosuspensions' physical properties, including saturation solubility, dissolution rate, physical stability, and in vivo performance, are influenced by both the mean particle size and particle size distribution. Various methods, such as photon correlation spectroscopy (PCS), laser diffraction (LD), and Coulter counter multisizer, can be used to analyse and determine the particle size distribution. The polydispersity index (PI), which indicates the particle size distribution's breadth, can also be measured using PCS. The particle size measured by PCS falls within the 3nm to 3µm range exclusively. A size distribution that ranges between 0.1-0.25 on the PI value scale indicates a relatively narrow distribution; however, if the PI value surpasses 0.5, it implies an exceptionally broad distribution. The utilization of Coulter-counter is highly efficient and appropriate in determining the absolute number of particles within distinct size categories per unit volume. It surpasses LD in quantifying the level of contamination caused by micro particulate pharmaceuticals in nanosuspensions.

Surface charges (Zeta potential)

The enduring physical stability and the surface charge characteristics of nanosuspensions can be inferred from the zeta potential. In order to maintain a stable suspension with electrostatic repulsion alone, a minimum zeta potential of ±30 mV is necessary, while a zeta potential of ±20 mV would be adequate for a mixture of electrostatic and steric stabilizers.

Crystalline state and particle morphology

Knowing the crystalline state and particle morphology aids in comprehending the potential polymorphic or morphological

shifts that could occur in a drug during nanosizing. The process of high pressure homogenization can result in a change in crystalline structure of nanosuspensions, potentially leading to amorphous or other polymorphic forms. X-ray diffraction and DSC may be utilized to ascertain alterations in the drug particles' solid state and percentage of the amorphous portion. However, to obtain a comprehensive understanding of particle morphology, scanning electron microscopy is highly recommended.

Saturation solubility & Dissolution velocity

Methods described in literature should be used to evaluate the saturation solubility of the drug in various physiological buffers and temperatures. Analyzing the dissolution velocity of nanosuspensions highlights the benefits that can be obtained when creating sustained release dosage forms centered around nanoparticulate drugs, as opposed to conventional formulations.

CONCLUSION

In this review, the aim was to detail the diverse methods used to create nanosuspensions. It was noted that generating nanosuspensions is a highly advanced process that requires an appropriate method from the several options available. Approaches like media milling and high-pressure homogenization have been effectively used for producing nanosuspensions on a large scale. Using emulsions or microemulsion as templates for production has resulted in simpler manufacturing techniques, however, there are certain limitations to this process.

References

1. Dubey R. Pure drug nanosuspensions impact of nanosuspensions technology on discovery and development. Drug Del.Tech., 2006; 6: 65-71.
2. Patravale VB, Date AA, Kulkarni RM. Nanosuspension: A promising drug delivery strategy. J Pharm Pharmacol. 2004; 56(7): 827–840.
3. Bharatia Vaibhavi Prashant, Mr. Ajay Talele., Dr. Anuradha Prajapati, Dr.Sachin B. Narkhede. Formulation development and evaluation of brain targeted Eslicarbamazepine acetate nanosuspension for Epilepsy, IJARIIE, 2021; 7(2): 2395-4396
4. Pattnaik S, Swain K, Rao JV. Nanosuspensions: a strategy for improved bioavailability. International Journal of Pharmacy and Biological Sciences, 2013; 3: 324-327.
5. Robert B, Raffa, Scott M, Rawls, Elena Portyansky Beyzarov. Netter's Illustrated Pharmacology. Saunders Elsevier, 1: 67-70.
6. Vaneerdenbrugh B, Vandenmooter G, Augustijns. Top-down production of drug nanocrystals: nanosuspension stabilization, miniaturization and transformation into solid products. International Journal of Pharmaceutics. 2008; 364(1): 64–75.
7. Dewaard H, Hinrichs W, Frijlink H. A novel bottom–up process to produce drug nanocrystals: controlled crystallization during freeze-drying. Journal of Control Release. 2008; 128(2): 179–83.
8. Keck C, Muller R. Drug nanocrystals of poorly soluble drugs produced by high pressure homogenization. European Journal of Pharmaceutics and Biopharmaceutics. 2006; 62(1): 3–16.
9. Nash R.A, Swarbrick J, Boylan J.C. Suspension dosage form. Encyclopaedia of pharmaceutical technology. Marcel Dekker, 2002; 2(3): 2045-3032.
10. RH Muller, C Jacobs and O Kayer. Nanosuspensions for the formulation of poorly soluble drugs. Int. F Nielloud, G Marti- Mestres. Pharmaceutical emulsion and suspension. New York, Marcel Dekker, 2000; 383-407.
11. Cornelia M. Keck, Rainer H. Muller. Drug nanocrystals of poorly soluble drugs produced by high pressure homogenization. European Journal of Pharmaceutics and Biopharmaceutics. 2006; 62: 3–16.
12. Alan Roy Dearn. Atovaquone pharmaceutical compositions. US Patent, 2000; US 6018080.
13. Prassanna L, Giddam A.K. Nanosuspensions technology, a review. International Journal of Pharmaceutics. 2000; 2(4): 35-40.
14. Liversidge GG, Cundy KC, Bishop JJ and DA Czekai. Surface modified drug nanoparticles. US Patent 5, 145, 684, 199.
15. Bodmeier R, Mc Ginity JM. Solvent selection in the preparation of poly (DL-lactide) microspheres prepared by solvent evaporation method. International Journal of Pharmaceutics. 1998; 43: 179–186.
16. 16.Trotta M, Gallarate M, Carlotti ME, Morel S. Preparation of Griseofulvin nanoparticles from water-dilutable microemulsions. International Journal of Pharmaceutics. 2003; 254(2): 235–242.
17. Young TJ, Mawson S, Johnston KP, Henriska IB, Pace GW, Mishra AK. Rapid expansion from supercritical to aqueous solution to produce submicron suspension of water insoluble drugs. Biotechnology Progress. 2000; 16(3): 402–7.
18. Kipp JE, Wong J, Joseph CT, Doty M, Mark J, Rebbeck C. Microprecipitation method for preparing submicron suspensions. 2000; US Patent, 6607784.
19. Arunkumar N, Deecaraman M and Rani C. Nanosuspension technology and its applications in drug delivery, Asian journal of pharmaceutics, 2009; 3(3): 168-173.
20. Chen Y, Liu J, Yang X, Zhao X, Xu H. Oleanolic acid nanosuspensions: Preparation, in-vitro characterization and enhanced hepatoprotective effect. Journal of Pharmacology and Pharmacotherapeutics. 2005; 57(2): 259-264.
21. Patel VR, Agrawal YK. Nanosuspension: An approach to enhance solubility of drugs. Journal of Advanced Pharmaceutical Technology & Research. 2011; 2(2): 81-87.
22. Shery Jacob, Anroop B. Nair and Jigar Shah. Emerging role of nanosuspensions in drug delivery systems. Biomaterials Research. 2020; 24: 3.
23. Ibrahim MA, Shazly GA, Aleanizy FS, Alqahtani FY, Elosaily GM. Formulation and evaluation of docetaxel nanosuspensions: in-vitro evaluation and cytotoxicity. Saudi Pharm J. 2019; 27(1): 49–55.
24. Hoang T, Zierden H, Date A, Ortiz J, Gumber S, Anders N. Development of a mucoinert progesterone nanosuspension for safer and more effective prevention of preterm birth. J Control Release. 2019; 295: 74– 86.
25. Gigliobianco MR, Casadidio C, Censi R, Di Martino P. Nanocrystals of poorly soluble drugs: drug

bioavailability and physicochemical stability. Pharmaceutics. 2018; 10(3): 134.
26. Phan ANQ, Bach LG, Nguyen TD, Le NTH. Efficient method for preparation of Rutin Nanosuspension using chitosan and sodium Tripolyphosphate Crosslinker. J Nanosci Nanotechnol. 2019; 19(2): 974–978.
27. Zhang Y, Zhang J. Preparation of budesonide nanosuspensions for pulmonary delivery: characterization, in vitro release and in vivo lung distribution studies. Artific Cells Nanomedicine Biotechnol. 2016; 44(1): 285 –289.
28. Xiaohui P, Jin S, Mo L, and Zhonggui H. Formulation of nanosuspensions as a new approach for the delivery of poorly soluble drugs, Current Nanoscience. 2009; 5(4): 417-427.
29. Mercadante S and Vitrano V. Pain in patients with lung cancer: pathophysiology and treatment, Lung Cancer.2010; 68(1): 10-15

How to cite this article:

Balusu Haarika, Hepsiba Rani CH and Divya Theja P (2023) 'Nanosuspensions - A Novel Approach For Various Drug Delivery Systems and Enhanced Solubility', *International Journal of Current Advanced Research*, 12(05), pp. 2057-2062. DOI: http://dx.doi.org/10.24327/ijcar.2023.2062.1451

****