RESEARCH PAPER

Nanotechnology compressive approaches in diabetic management: methodology and characterization of nanoparticle

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ABSTRACT

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1. INTRODUCTION

Diabetes mellitus (DM) a global health concern which is characterized by hyperglycemia resulting from impaired insulin secretion or action. It is classified into Type 1 diabetes (T1D), Type 2 diabetes (T2D), and gestational diabetes. Conventional antidiabetic drugs including insulin injections and oral hypoglycemic agents face challenges such as poor solubility, gastrointestinal degradation, and systemic side effects. Nanotechnology-based drug delivery systems offer promising solutions by enhancing drug stability, targeted delivery, and controlled release. This review provides an overview of recent advancements in Nano-based antidiabetic agents and their role in diabetes management.

2. NANOTECHNOLOGY IN DIABETES MANAGEMENT

Nanotechnology involves the design and application of materials at the nanoscale (1-100 nm) to improve drug delivery and therapeutic efficacy. The use of nanoparticles (NPs) in diabetes treatment enhances bioavailability, reduces side effects, and provides controlled drug release.

2.1 Types of Nano-Based Antidiabetic Agents

Polymeric Nanoparticles: Biodegradable and biocompatible carriers such as chitosan and PLGA improve drug encapsulation and release profiles.

Lipid Based Nano carriers: Liposomes, solid lipid nanoparticles (SLNs), and nanostructured lipid carriers (NLCs) enhance drug stability and absorption.

Metallic Nanoparticles: Gold, silver, and zinc oxide nanoparticles exhibit anti-inflammatory and insulin-mimetic properties.

Carbon Based Nanomaterials: Graphene oxide and carbon nanotubes (CNTs) provide efficient glucose sensing and drug delivery platforms.

Protein Based Nanoparticles: Albumin and silk fibroin-based nanoparticles facilitate targeted drug release.

3.0. METHODS OF PREPARATION

Methods of preparation can be classify in to bottom-up, top-down, bottom-up and top-down, and spray drying. Bottom up technique involve nanoprecipitation method. Milling and homogenization methods are part of top down methods while in bottom-up and top-down method involve application of both methods together bottom-up methods also known as low energy methods and high energy refers for top –down methods.

3.1. Precipitation methods

This process has been used to produce nanoparticles since 1980. Drug is dissolved in an organic solvent using this straightforward method, and excipients such as stabilizer and polymer surfactant are dissolved in a miscible inorganic solvent. The organic solvent is then added to the inorganic solvent with spontaneous agitation, resulting in particle precipitation. The limitations of this procedure are that it requires the API to be soluble in at least one organic solvent and that organic solvent to have the ability to mix with inorganic solvents.

3.2. Milling Method

The development of this technology began in 1990. This method involves filling the milling chamber with milling pearls and surfactant and then applying high rotation with a motor to create suspension-like nanoparticles. This technique takes a long time to produce since factors like drug hardness and quantity can affect it. High energy is required for this process, and occasionally pearl erosion results in product deterioration and increases the danger of bacterial and microbiological contamination. The drawbacks of this approach are that it takes a long time and that milling could cause suspension instability.

3.3. Homogenization Method

In 1990, this method was created to create nanoparticles and Nano suspensions. Using a high kinetic force, the API and excipient Nano suspension is passed from the homonizer gap at high pressure, causing cavitation and producing nanoparticles. In a high-pressure homogenizer, a unique product can be produced by applying both mechanical force and pressure. The homogenizer can also be adjusted to produce the desired particle size by varying the pressure and force. Additionally, it offers a temperature-changing function. High temperatures are utilized in the hot homogenization process to melt the lipoids phase and produce the aqua phase. Drugs that can be heated to high temperatures shouldn't be treated using this technique. We can employ cold homogenization techniques for that kind of medication. Additionally, this technology is used in the manufacturing of food and cosmetics as well as in the formulation of pharmaceuticals.

3.4. Spray drying

To create spherical particles, hot air dries solution droplets sprayed from top to bottom in a conical or cylindrical cyclone in the same direction. Using a nebulizer that spins rapidly because of the centrifugal action, the solution is sprayed. The outer tube receives nitrogen or air under constant pressure, while the inner tube receives the solution at a predetermined flow rate via a peristaltically operated pump. Through the nozzle, the spray is applied. The solution's droplets shrink significantly when sprayed. As a result, the desiccant's surface area grows, hastening drying.

4.0. CHARACTERIZATION OF NANOPARTICLE

4.1. Nanoparticle Size:

In order to monitor the dissolution, saturation solubility, and physical and biological stability of nanoparticles, it is crucial to detect their size by employing photon correlation spectroscopy (PCS), the mean particle size is found. Laser diffraction (LD) and Coulter counter-miltisizer are also used to verify this characteristic. Particle width can also be measured with the PCS method. In the industrial sector, the dynamic light scattering method (DLS) is also employed to measure the size of nanoparticles, including those smaller than 10 nm.

4.2. Shape and Morphology:

This feature can be verified using scanning electron microscopy (SEM) and transmission electron microscopy (TEM). A solid sample is needed for SEM, and a liquid or wet sample is needed for TEM. SEM can occasionally be used to measure the Nano suspension size therefore lyphillization or drying techniques are employed to extract the solvent from the suspension. Additionally, polymorphic changes brought on by pressure and homogenization can be detected using x-ray diffraction (XRD).

4.3. Zeta Potential

The stability of colloidal dispersion following storage can be determined with the help of this measurement. Zeta potential between ±20 to ± 30 mv is stable for nanoparticle. Zeta potential measure by zetasizer.

4.4. Differential Scanning Calorimetric (DSC)

This technique is employed to identify interactions between the medicine and excipients. One can determine the melting point and interaction by utilizing a thermogram of pure API and a mixture of excipients with API.

4.4. Measurement of entrapment efficiency

The technique known as cold centrifugation utilizing micro centrifuge was used to assess entrapment efficiency. Centrifugation was carried out at 10,000 rpm for 20 minutes using an SLN and polymeric nanoparticle dispersion with 2 mg EW. Following centrifugation, the liquid supernatant was examined. This liquid was pipetted and then diluted to a volume of 10 milliliters. A UV spectrophotometer was used to measure the sample's absorbance. Using following formula entrapment efficiency can be determine.

% EE = Total amount of drug – Unloaded polymers / Total amount of drug * 100

4.5. *In vitro* dissolution estimation

The dialysis bag approach was used to determine in vitro dissolution. The release study made use of dialysis membrane. The dialysis membrane was immersed in distilled water for 24 hours prior to the release tests. Nanoparticle weighing 2 mg equivalent weight were added to the dialysis that is tied at both ends. After fixing the dialysis membrane in a beaker with 50 ml of phosphate buffer pH 6.8, the solution was agitated at 50 rpm with a magnetic stirrer while the temperature was kept at 37±0.5 °C.

5.0 THERAPEUTIC APPLICATION

5.1. Dermal

Applying a medicine to the skin and allowing it to be absorbed through the lipid intercellular pathway, the transcellular pathway, or follicular penetration is known as dermal usage. The nanoparticle increases the gradient of concentration between the skin and the nano formulation, which increases transdermal penetration. By transforming the nano formulation into lotion or cream form, local action can also be obtained on the mucosal layer, and nano spray can also be helpful.

5.2. Ocular

For poorly soluble medications, a nano ointment or suspension is made to be applied to the eye. This has the benefit of providing long-lasting effects and excellent performance, but it also has the drawback that most drugs have a lawful solubility in lachrymal fluid, which results in a lawful concentration of the drug at the desired location. In addition to reducing drug loss in lachrymal fluid, nanoparticles can transform into slaw release formulations for extended use.

5.3. Parenteral

Drug retention and tumor penetration are enhanced by using nanoparticles with sizes ranging from 0.1 μm to 0.3 μm. Mycoepoxydine is one of the medications used to treat cancer that is sold as an intravenous formulation. Other excipients are coated on nanoparticles to lessen opsonic assault and have a long-lasting effect on tumors. By changing the surface of the nanoparticle, it can be utilized to treat serious illnesses like HIV and TB by changing the plasma protein. 1, 3-dicyclohexylurea is used to lower blood pressure and can be administered intravenously.

5.4. Oral

Oral administration of nanoparticles can take the form of direct compressed tablets, capsules, nano suspensions, or various tablet forms. Focusing on the drug's solubility and absorption into gastric juice, which facilitates absorption into the blood and provides the necessary effect, is essential for optimal therapeutic action. Certain factors are noted for oral use, such as the GIT tract's pH, the drug's solubility, dosage, and food interactions, among others.

5.5. Subcutaneous

Subcutaneous refers to the administration of a medication beneath the epidermis. When intravenous drug administration is not feasible or affordable, this method is employed. The medication is administered to the adipose tissue beneath the skin. The abdomen, arm, and thing are the typical locations. The Amgen Company manufactures nanoparticles for use in chemotherapy of neutropenic cancer by combining PEG and Granulocyte Colony Stimulating Factor under the brand name Neulasta.

5.6. Targeted Delivery

Certain nanoparticles with unique sensors are also utilized to identify cancer cells in blood, allowing for the early detection of the disease. Additionally, nanoparticles are employed to create nanosprays that are helpful for detecting gene protein sequences and deoxyribonucleic acid.

6.0. RECENT ADVANCES IN NANO-BASED ANTIDIABETIC THERAPY

6.1 Insulin Nano delivery Systems

Oral Insulin Nanoparticles: Overcoming enzymatic degradation for effective glucose regulation.
Inhalable Insulin Nanoparticles: Improving patient compliance and rapid absorption.
Transdermal Nano patches: Providing non-invasive insulin delivery with controlled release.

6.2 Plant-Based Nanomedicine for Diabetes

Curcumin Nanoparticles: Enhancing bioavailability of curcumin, a potent antidiabetic phytochemical.
Resveratrol Nanoparticles: Improving glucose metabolism and insulin sensitivity.
Bebeerine-Loaded Nanoparticles: Increasing solubility and efficacy of bebeerine, a traditional antidiabetic agent.

6.3 Smart Nano systems for Glucose Sensing and Drug Delivery

Glucose-Responsive Nanoparticles: Releasing insulin in response to glucose levels.
Wearable Nano sensors: Providing continuous glucose monitoring for real-time diabetes management.
Artificial Pancreas with Nanotechnology: Integrating biosensors and Nano carriers for automated insulin release.

7.0. CHALLENGES AND FUTURE PERSPECTIVES

Despite the promising advancements, several challenges remain in the clinical translation of Nano-based antidiabetic therapies
Biocompatibility and Toxicity long-term effects of nanoparticles need extensive investigation.
Regulatory approval stringent regulations and safety assessments delay commercialization.
Scalability and Cost high production costs limit widespread application in diabetes management.
Patient Acceptance public awareness and acceptance of nanomedicine must be improved.

Future Directions

Personalized Nanomedicine: Tailoring Nano-based treatments to individual patient profiles.
Advanced Biomaterials: Development of biodegradable and self-assembling Nano carriers.
Integration with Digital Health: Combining nanotechnology with AI-driven glucose monitoring for precision medicine.

8.0. CONCLUSION

Nano-based antidiabetic agents represent a groundbreaking advancement in diabetes management by improving drug bioavailability, stability, and targeted delivery. While significant progress has been made, further research and clinical trials are needed to ensure their safety, efficacy, and regulatory approval. With continued innovation, nanotechnology holds the potential to revolutionize diabetes therapy and improve patient outcomes.

REFERENCES

[1] Gao L, Zang D, Chen M (2008) Drug Nanocrystal for Formulation of Poorly Soluble Drug and Its Application as Potecial Drug Delivery System. J Nano Part Res 10(1): 845-862.

[2] Peltonen L, Hirvonen J (2018) Drug Nanocrystal Versatile Option for Formulation of Poorly Soluble Material. International Journal of Pharmaceutics 537(1-2): 73-83.

[3] Nagarajan R (2008) Nanoparticles: Building Blocks for Nanotechnology. American Chemical Society pp: 2-14.

[4] Junyaprasert VB, Morakul B (2015) Nanocrystal for Enhancement of Oral Bioavailability of Poorly Water Soluble Drugs. Asian journal of Pharmaceutical Science 10(1): 13-23.

[5] Sun B, Yeo Y (2012) Nanocrystals for the Parenteral Delivery of Poorly water-soluble drugs. Current Opinion in Solid State and Materials Science 16(6): 295-301.

[6] Pitaksuteepong T (2005) Nanoparticle: A Vaccine Adjuvant for Subcutaneous Administration. Naresuan University Journal 13(2): 53-62.

[7] Roy I, Ohulchanskyy TY, Pudavar HE, Bergey EJ, Oseroff AR, et al. (2013) Ceramic based nanoparticles entrapping water-insoluble photosensitizing anticancer drugs: a novel drug-carrier system for photodynamic therapy. Am Chem Soc 125(26): 7860-7865.

[8] Carretero OA, Oparil S. Essential hypertension. Part I: definition and etiology. Circulation. 2000;101(3):329-35. 10.1161/01.cir.101.3.329. PMID 10645931.

[9] Choudhury A, Laskar RE, Deka D, Sonowal K, Saha S, Dey BK. A review on nanoparticle: types, preparation and its characterization. Res J Pharm

Technol. 2021;14(3):1815-22. doi: 10.5958/0974-360X.2021.00322.X.

[10] Shaveta S, Singh J, Afzal M, Kaur R, Imam SS, Alruwaili NK. Development of solid lipid nanoparticle as carrier of pioglitazone for amplification of oral efficacy: formulation design optimization, *in vitro* characterization and *in vivo* biological evaluation. J Drug Deliv Sci Technol. 2020;57. doi: 10.1016/j.jddst.2020.101674.

[11] Dudhipala N, Janga KY, Gorre T. Comparative study of nisoldipine-loaded nanostructured lipid carriers and solid lipid nanoparticles for oral delivery: preparation, characterization, permeation and pharmacokinetic evaluation. Artif Cells Nanomed Biotechnol. 2018;46(2)Suppl2:616-25. doi: 10.1080/21691401.2018.1465068, PMID 29688077.

[12] Agrawal YO, Husain M, Patil KD, Sodgir V, Patil TS, Agnihotri VV. Verapamil hydrochloride loaded solid lipid nanoparticles: preparation, optimization, characterisation, and assessment of cardioprotective effect in experimental model of myocardial infarcted rats. Biomed Pharmacother. 2022;154:113429. doi: 10.1016/j.biopha.2022.113429, PMID 36007280.

[13] Nazief AM, Hassaan PS, Khalifa HM, Sokar MS, El-Kamel AH. Lipid-based gliclazide nanoparticles for treatment of diabetes: formulation, pharmacokinetics, pharmacodynamics and subacute toxicity study. Int J Nanomedicine. 2020;15:1129-48.doi: 10.2147/IJN.S235290, PMID 32110012.

[14] Shidhaye SS, Vaidya R, Sutar S, Patwardhan A, Kadam VJ. Solid lipid nanoparticles and nanostructured lipid carriers-innovative generations of solid lipid carriers. Curr Drug Deliv. 2008;5(4):324-31. doi: 10.2174/156720108785915087, PMID 18855604.

[15] Abdel Moneim A, El-Shahawy A, Yousef AI, Abd El-Twab SM, Elden ZE, Taha M. Novel polydatin-loaded chitosan nanoparticles for safe and efficient type 2 diabetes therapy: in silico, *in vitro* and *in vivo* approaches. Int J Biol Macromol. 2020;154:1496-504. doi: 10.1016/j.ijbiomac.2019.11.031, PMID 31758992.