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ZEIN BIOPOLYMER FOR ADVANCED DRUG DELIVERY: A SUSTAINABLE AND FORGOTTEN RESOURCE

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ABSTRACT:-

A proline protein zine derived from maize, a promising yet for pharmaceutical drug delivery, represents an unexploited biopolymer. Recognized by regulatory agencies (GRAS), Zeen provides an excellent combination of biodegradability, biocompatibility, hydrophobicity, and film-making ability. These properties enable ZEIN to function as a versatile platform for advanced drug distribution, including nanotherapy, microparticles, hydrogels, movies, and nanofibers. Zein-based yogas have been shown to control the solubility, stability, and bioavailability of poor water-soluble drugs while offering controlled and continuous release profiles. Its natural ability to self-decorate in colloidal structures provides a simple but efficient method for encapsulation of hydrophobic and sensitive bioactives. Despite its early industrial use in coatings and food packaging, the zen has been forgotten in pharmaceutical science compared to widely used biopolymers such as chitosan, alginet, and PLGA. Current studies display their potential in oral, nasal, transdermal, and parenteral delivery, as well as peptide, protein, and nucleic acid transport. In addition, the renewable originality and cost-effectiveness of the zain align with the increasing global demand for environmentally friendly and durable excipients. However, challenges such as hydrophobicity-related formulation difficulties and variability between natural sources still limit large-scale applications. This review emphasizes the zain as a permanent and forgotten resource with heavy ability to replace drug delivery platforms. Future research in zeen composite, smart polymer hybrid, and excitement-existence systems can re-establish this biopolymer

KEYWORD:- Zein biopolymer, Drug delivery systems,Biodegradable polymers, Sustained release, Controlled release, Oral drug delivery, Protein-based polymers

INTRODUCTION:-

In the last two decades, the pharmaceutical industry has moved towards biopoller as an alternative to traditional synthetic exercises for drug distribution systems. Biopolymers derived from natural sources provide the benefits of biodegradability, biocompatibility, safety, and stability, meeting the increasing demand for environmentally friendly drug technologies. Generally studied natural polymers-such as chitosan, alginet, gelatin, and starch-zeen, a plant from the endosperm of maize, remains relatively unlocked in pharmaceutical protein, drug research. Although it was one of the industrially applied initial proteins in coatings and packaging, its unique functional characteristics for drug distribution were largely ignored, left as "forgotten resources" in modern pharmaceutics.

The zain has a specific hydrophobic amino acid structure, which makes it soluble in aqueous ethanol but is insoluble in water. The property allows the zen to self-decide in nanopartens, microparticles, nanofibers, and films, which can be effectively used to encounter both hydrophobic and hydrophilic bioactive compounds. In drug delivery applications, Zeen has shown great promise to improve poor water soluble drug soluble drug solutions, stability, and oral bioavailability, while enabling the continuous and controlled release of medical molecules. Importantly, the zain is classified by the American Food and Drug Administration as "generally secured as" (GRAS), which further strengthens its ability to translate into drugs and nutracutical yogas.

The recent progress in nanotechnology has revived the zeen as a versatile carrier for drugs, peptides, proteins, and genetic materials.

Despite its benefits, some limitations, such as strong hydrophobicity, variability in natural sources, and relatively limited large-scale drug use, prohibit its widespread application. However, ZEIN provides promising solutions in research related to composite, polymer combination, and functional modification. By integrating the zain into advanced and excitement-ex-distribution systems, this natural protein can re-emerge as a permanent and valuable stimulant in modern pharmaceutical science.

ORIGIN AND PROPERTIES OF ZEIN: -

ORIGIN OF ZEIN

Zeen is the major storage protein found in the endosperm of maize (Zea mays l.), which is an accounting for about 40–50% of the total protein content in corn. It belongs to the family of prolamin, which is a soluble protein soluble in alcohol and glutamine. The name "Zeen" was taken under the name of Mecca itself. It was first isolated in the early 19th century and since then, its hydrophobicity and strong film-making nature have been widely used in food, coatings, textile, and packaging industries.

The extraction of the zain is usually done using aqueous ethanol or aqueous isopropyl solutions, sometimes assisted with alkali or reducing agents to improve yield and purity. Protein is classified into four degrees based on solubility and molecular characteristics: α-zein (major fractions, ~ 80%), β-zein, γ-zein, and δ-zein. Of these, α-zein is studied on the largest scale due to its abundance and favorable physical and chemical properties.

ZEN PROPERTIES:-

1. Chemical composition

Zein is rich in hydrophobic amino acids such as lycene, allenin, and promin, along with a decrease in lysine and triptophane.

This hydrophobicity is responsible for its water efficiency, but has excellent solubility in aqueous ethanol, acetone, and some alkaline solutions.

2. Biodegradability and biocompatibility

as a natural protein, the zen is completely biodegradable and biocompatible.

U.S. The FDA is generally considered by the FDA as a safe (GRAS), which supports its direct application in nutraceuticals and pharmaceuticals.

3. Film and fiber formation

The O Zeen can make transparent, shiny, and hydrophobic films, which are resistant to moisture and grease.

Through O electrospinning, the Zen can also produce nanofibers

4. Self-government and encapsulation capacity

Causes of its amphifilic nature, the zen can be self-guttar in colloidal nanopraths and microprarticles in aquatic media.

This makes drug encapsulation, controlled release, and hydrophobic drugs and sensitive biomolecules especially useful for increasing.

5. Mechanical and thermal stability

ZEIN movies and particles demonstrate high mechanical strength and good thermal stability, causing them to face processing and storage.

ZEIN'S DRUG APPLICATION:-

Zeen has gained renewed interest in the drug field due to its biodegradability, biocompatibility, and its properties. Its ability to create nanoparticles, microparticles, films, and fibers provides a versatile platform for drug distribution in many administration routes.

1. Nanoparticles and microprartles

• Zeen naturally collects in colloidal nanoparticles when it is spread in an aquatic environment.

• These nanoparticles can surround poorly soluble or hydrophobic drugs such as curcumin, paclitaxel, and resveratrol, and their solubility and oral bioavailability can significantly improve.

• Zain -based microparticles are widely controlled and studied for continuous release yogas, especially for oral drug delivery.

2. Oral drug delivery

• The zain protects encapsulated drugs from the fall in the acidic gastric environment.

• Studies have shown that zeen nanoparticles increase the oral distribution of insulin, peptides, and vitamins.

• Zain-based coatings on tablets and capsules can provide targeted colon distribution due to resistance to gastric fluids.

3. Parenteral and Injectable System

• Zeen Nanoparticles have been developed for anticancer drug delivery, where they provide continuous release and reduce systemic poisoning.

• His ability to bind hydrophobic anticancer agents makes them a potential carrier for intravenous yogas.

4. Transdermal and topical application

• ZEIN movies and nanofibers act as excellent barrier materials, which are suitable for wound dressing, skin patches, and topical pharmaceutical carriers.

• Electrospun zine nanofibers can include development factors for antibacterial agents, anti -anti-inflammatory drugs, and wound healing, and use in tissue regeneration.

5. Gene and Protein Distribution

• Zein nanoparticles have been used for DNA, siRNA, and protein distribution due to their protective effects against enzymatic decrease

• Their natural cationic surface can be revised to improve nucleic acid binding and cellular uptake, making them candidates for gene therapy.

6. Conjunction and hybrid system

• Zeen has been mixed with polymers such as chitosan, hyaluronic acid, and PEG to improve drug loading, release, canetex, and mucoradesians.

• Zeen Composite has been applied in mucoradic book delivery and stimulation-ex-systems for targeted therapy.

ZEIN IN ADVANCED DRUG DELIVERY SYSTEMS:-

Recent developments in Nanotechnology and Material Science have focused the focus of pharmaceutics towards the Advanced Drug Delivery System

(DDS) that offers targeted, continuous, and efficient therapeutic results. In this context, a corn-reputed prolamine protein, zeen, has attracted attention due to its unique ability to form self-assembly in various nanostructures, produce biocompatible films, and serve as a protective carrier for both hydrophobic and sensitive biomolecules. Beyond its traditional use in coatings and neutrasuticals, the zeen is now being discovered in state -of -the -art distribution systems including nanopakans, nanofibers, gene delivery vectors, and mucoradesive carriers.

1. Zeen nanoparticles and nanospheres

• Zeen nanopathy and nanosphere can cause self-discomfort through self-reliance, rain, and spray drying techniques.

• These nanocations provide continuous release and improve the oral bioavailability of poorly soluble drugs such as curcumin, paclitaxel and resveratrol.

• Functional zeen nanoparticles (eg, pegylated or chitosan-coated) show extended mucosal stability and target distribution.

2. Zeen in Mucodesiv drug delivery

• ZEIN has been paired with Mucocaidesiv polymers such as chitosan, alginate, and hyaluronic acid to improve retention on mucosal sites.

• Applications include peptides, nasal sprays, and bookcall delivery of ocular yogas.

• This strategy increases the local bio -bioavailability of medical agents at absorption sites.

3. Zeen Nanofibers and Electrospun System

• Using electrospinning, the zein can form nanofibers with high surface area and porosity.

• These nanofibers are used in transdermal patches, wound healing systems, and tissue engineering scaffolds.

• They allow antimicrobial agents, growth factors, and anti -anti-inflammatory drugs for controlled topical distribution.

4. Gene and Protein Distribution

• Zeen-based carriers protect protein, peptides, and nucleic acids (DNA, SIRNA) from enzymatic decrease

• Modified zeen nanoparticles (cationic or ligand-conjugated) increase cellular uptake and targeted distribution of genetic materials.

• It gives position to the zen as a possible carrier in gene therapy and protein replacement therapy

5. Smart and stimulation system

• Zeen has been integrated into site-specific drug release in pH-sensitive, enzyme-responsive, and redox-excellent systems.

• Example: Zeen-Chitosan Nanoparticles are designed for colon-specific drug distribution.

• Smart zeen system is being studied for cancer therapy, inflammatory diseases, and accurate medicine.

BENEFITS OF ZEEN ON OTHER BIOPOLYMERS:-

Natural biopolymers such as chitosan, alginate, gelatin, and starch are widely used in pharmaceutics. However, each has limitations, including poor stability, limited drug loading, or regulatory restrictions. A corn-specific prolamine provides protein, zain, and many unique benefits that distinguish it from other biopolymers and make it a valuable candidate for advanced drug distribution applications.

1. Plant-based and renewable origin

Unlike animal-rich polymers (eg, gelatin, collagen, chitosan), Zain is extracted from maize endosperm, making it a plant-based, vegetarian, and durable stimulant.

2. GRAS status and regulator acceptance

The ZEIN is classified by the American FDA as "commonly recognized (commonly recognized)", giving it a regulatory advantage over other biopolymers that may require extensive toxic testing. This condition allows direct use in neutraceuticals and pharmaceuticals, which accelerates translations in marketing yoga.

3. Self-illiterate and versatile structures

• Zeen can be self-gutted in nanopartens, microparticles, movies and nanofibers without the need for rigid solvents or complex chemistry.

• Many other polymers require cross-linking agents, which can introduce toxicity.

This makes Zein a safe and more straight carrier for advanced yogas.

4. Cost-effectiveness and abundance

• By the Corn Processing Industry -Products, the Zen is abundant and relatively low-cost.

CHALLENGES AND LIMITATIONS OF ZEIN IN PHARMACEUTICAL APPLICATIONS:-

Although the zen provides several promising benefits on other biopolmers, its pharmaceutical application is still limited. Like most natural materials, Zen is encountered, stability and regulatory challenges that prohibit its widespread use in advanced drug distribution systems. It is necessary to understand these boundaries to direct future research and improve its performance.

1. Poor aquatic solubility

• Zeen is naturally hydrophobic, which makes it poorly soluble in water and physical fluids.

• It prohibits its use in the rapid disruptions or the ingredients required by intravenous distribution.

• Unlike hydrophilic polymers such as alginate or starch, zain requires organic solvents or pH adjustment, which can increase safety concerns.

2. Limited mechanical strength and flexibility

• Although the zen makes strong movies, they can be brittle compared to polymers such as chitosan or gelatin and may lack flexibility.

•It reduces their projection in coatings and transdarma systems until it is mixed with a plasticizer or a secondary polymer.

3. Physiology

• Zeen nanoparticles can undergo aggregation or rapid decline in gastrointestinal fluids.
• This instability affects the drug release content and can cause premature drug leakage before reaching the target site.
• This variability released has drug loading, encapsulation efficiency and anomalies in the release profile, which makes scale-ups challenging.

4. Limited activity

• The zain lacks sufficient reactive functional groups for chemical modifications compared to other biopolymers such as chitosan (Amin group).
• It prohibits its ability to be conjugated with ligands, antibodies, or targeted moieties without complex modification stages.

5. Regulatory and industrial challenges

• While Zain is FDA-Grass for food use, drug regulatory approval requires more evidence of long-term safety, biodegradation, and toxicity.
• Production of similar zeen nanoparticles on an industrial scale with controlled size and release remains a technical challenge.

FUTURE PERSPECTIVES OF ZEIN IN DRUG DELIVERY:-

Increasing interest in durable, safe, and efficient drug delivery systems highlights the unused capacity of a plant-rich biopolymer, zen. While its unique hydrophobicity, biocompatibility, and the ability of film-formation make it promising, solubility, stability, and current boundaries in massiveness should be addressed. Further, emerging technologies and material engineering strategies can convert zein into a widely accepted drug Excipient.

1. Nano-technology-run formulation

Nanoparticle engineering provides opportunities to overcome issues of advanced zain solubility and stability. The development of zeen-based nanocarers, including hybrid nanopakans, Michaels, and Nanofibers, can provide controlled drug release, better bioavaling and targeted distribution. With smart nanocheriers such as excitement-respondent polymer, they will open new avenues for accurate medicine.

2. Polymer -combination and functional amendment

Future yoga can integrate the zain with other natural or synthetic polymers (eg, chitosan, PEG, alginate) to improve mechanical strength, solubility and drug encapsulation efficiency. Chemical modifications, such as grafting of functional groups or targeting ligands, can increase the specificity of the zen for cancer therapy, gene delivery, and protein stabilization.

3. Advanced manufacturing approach

Techniques such as electroplating, 3D printing, and microfluidics promise to develop zen-based micro/nanostructures with accurate architecture.

CONCLUSION

A plant-disconnected is recognized as a versatile and durable bioparticle for protein drug applications. Its unique combination of biocomatability, biodegradation, film-forming capacity and self-Iltirsi properties enables the development of drug distribution systems including nanocystms, microparticles, films, fiber and hybrid carriers. Research has highlighted Zen's ability to increase poor water drugs to increase solubility, stability and bioavailability, while also offered protection against rigid gastrointestinal environment. These properties make it a promising candidate for oral, injection, transdermal and gene delivery platforms.

Other biopolore such as chitosan, gelatin and albic, zeen hydrophobic drugs provide a clear advantage in terms of encounter, grass conditions and renewable sourcing. However, it also faces important challenges, including poor aquatic solubility, limited mechanical flexibility, batch-to-batch variability and regulatory obstacles. These limitations currently prohibit its widespread adoption in mainstream drugs.
In addition, nanotechnology provides promising strategy to remove these obstacles to remove these obstacles. Zen's possible role in Emerging Medical Fields Sukh as biologics, gene therapy and vaccine delivery highlights its relevance in the next generation pharmaceutics. In addition, its plant-based original and biodegradability aligned well with the increasing demand for green and sustainable drug distribution systems.

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